2008
Direct-Reading Exposure Assessment Methods

D.R.E.A.M.
WORKSHOP

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

CDC Workplace Safety and Health

NIOSH

Proceedings: 2008 Direct-Reading Exposure Assessment Methods Workshop

Edited by Christopher Coffey, Ph.D. and Ainsley Weston, Ph.D.

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2008 DIRECT-READING EXPOSURE ASSESSMENT METHODS

NOVEMBER 13 and 14, 2008
ARLINGTON, VIRGINIA

Direct-reading Exposure Assessment Methods (D.R.E.A.M.) Workshop

It is my pleasure to welcome you to the workshop on ***Direct-reading Exposure Assessment Methods (D.R.E.A.M.).*** The National Institute for Occupational Safety and Health along with the American Industrial Hygiene Association, the American Chemistry Council, the Center for Construction Research and Training, the U.S. Department of Energy, the U.S. Department of Homeland Security, the Health Physics Society, the International Association of Fire Fighters, the International Safety Equipment Association, the National Institute of Standards and Technology, ORC Worldwide, and the Technical Support Working Group of the Combating Terrorism Technology Support Office, Department of Defense, have come together to sponsor the workshop.

Great opportunities exist to harness twenty-first century technologies to improve and develop new direct-reading analytical techniques and direct-reading instruments to accurately assess exposures in time-sensitive ways and to support appropriate actions to assure worker and public health. The unique requirements and applications of direct-reading methods in both routine occupational activities and emergency preparedness include the need to develop improved laboratory and field test capabilities, along with a comprehensive suite of standard reference materials and values that can be used to evaluate and validate the method or instrument performance and the interpretation of their results.

NIOSH looks forward to working with stakeholders to assess and improve methods and guidance for assessing a range of workplace stressors and agents including ergonomic factors, dusts, mists, fumes, nanoparticles and other aerosols, biological agents, gases and vapors, metals, noise, radiation, pesticides and other chemicals. Thank you for your participation in this effort.

Christine M Branche

Christine M. Branche, PhD
Acting Director, National Institute for
Occupational Safety and Health
Centers for Disease Control and Prevention

Acknowledgments

The Direct-Reading Exposure Assessment Methods Workshop planning committee would like to thank Teri Palermo, Catherine Calvert, and Brenda Boutin of NIOSH, LaKeyshia Alexander and Bridgette L. Saunders of Professional and Scientific Associates (PSA), and the management and staff of the Hilton Crystal City at Washington Reagan National Airport for their assistance.

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Organizations

American Industrial Hygiene Association

American Chemistry Council

The Center for Construction Research and Training

Health Physics Society

International Association of Fire Fighters

International Safety Equipment Association

National Institute of Standards and Technology

ORC Worldwide

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University of South Florida, College of Public Health

U.S. Department of Energy

U.S. Department of Homeland Security

Individuals

Jeri Anderson
NIOSH

Vern Anderson
NIOSH

Kevin Ashley
NIOSH

Rebecca Blackmon
Technical Support Working Group

Christine Branche
NIOSH

Robert Brauch
Larson-Davis, AIHA

Mike Brisson
SRS

Brenda Boutin
NIOSH

Cathy Calvert
NIOSH

Christopher Coffey
NIOSH

Acknowledgments

Michael Commodore
NIOSH

Morgan Cox
International Standards Consultant

Gayle DeBord
NIOSH

Pamela Drake
NIOSH

Matthew Duling
NIOSH

John Earshen
Angevine Consultants, AIHA

Peter Görner
INRS

Jason Ham
NIOSH

Richard Hansen
National Security Technologies LLC

Martin Harper
NIOSH

William Heitbrink
University of Iowa

Mark Hoover
NIOSH

John Howard
Consultant

Judy Hudnall
NIOSH

Cynthia Jones
NRC

Chuck Kardous
NIOSH

James Knoll
NIOSH

Brian Lowe
NIOSH

Dean Lillquist
OSHA Salt Lake Technical Center

Robert Lawrence
NIOSH

David Mark
Health & Safety Laboratory, UK

Matthew Magnuson
EPA

Mark Maiello
Wythe Research

Robert McCleery
NIOSH

Raymond McGorry
Liberty Mutual Research Institute for Safety

John Meeker
University of Michigan

Mark Methner
NIOSH

Paul Middendorf
NIOSH

Jayne Morrow
National Institute of Standards and Technology

Dennis O'Dell
MSHA

Teri Palermo
NIOSH

Acknowledgments

Terri Pearce
NIOSH

Michael Philips
Menssana Research, Inc.

G. Richard Price
Auditory Hazard Analysis

Robert Radwin
University of Wisconsin-Madison

Stephen Rappaport
University of California, Berkeley

Deborah Sammons
NIOSH

John Seiler
MSHA

Pam Susi
CPWR

Charles Timchalk
Pacific Northwest National Laboratory

Jon Volkwein
NIOSH

John Snawder
NIOSH

Jay Snyder
NIOSH

Mark Spence
Dow Chemical

Peng-Yau (Eric) Wang
National Central University, Taiwan

David Weissman
NIOSH

Wassana Yantasee
Pacific Northwest National Laboratory

Ted Zellers
University of Michigan

Direct-Reading Exposure Assessment Methods Workshop Planning Committee

Chris Coffey (chair)
Jeri Anderson
Vern Anderson
Kevin Ashley
David Byrne
Gayle DeBord
Pam Drake
Jason Ham
Martin Harper
Mark Hoover
Chuck Kardous
Brian Lowe
Rob McCleery
Mark Methner
Paul Middendorf
Terri Pearce
Debbie Sammons
John Snawder
Jay Snyder
Jon Volkwein

Direct-Reading Exposure Assessment Methods Workshop Monitor/Rapporteur/Speaker Biographies

Jeri L. Anderson, Ph.D. received her B.S. in Physics, M.S. in Health Physics, and Ph.D. in Nuclear Engineering from the Georgia Institute of Technology and was awarded a postdoctoral fellowship at the Lovelace Respiratory Research Institute in Albuquerque, New Mexico. In between undergraduate and graduate degrees she worked on offshore oil rigs in the Gulf of Mexico as a field engineer for Schlumberger Well Services. She is a Health Physicist in the Occupational Energy Research Program of the Industry-Wide Studies Branch (IWSB), Division of Surveillance, Hazard Evaluations, and Field Studies (DSHEFS), National Institute for Occupational Safety and Health (NIOSH), a position she has held since June 2004. She is primarily responsible for performing retrospective radiation exposure assessments for epidemiological studies of workers occupationally exposed to radiation and radioactive materials. She is a member of the Health Physics Society, the American Nuclear Society, and the Cincinnati Radiation Society. Previously, Dr. Anderson was employed as a senior internal dosimetrist and consulting health physicist with a private radiological consulting firm outside Buffalo, New York.

Kevin Ashley, Ph.D. is currently a research chemist for the National Institute for Occupational Safety and Health, Division of Applied Research and Technology in Cincinnati, OH. Dr. Ashley was the recipient of the CDC/NIOSH Alice Hamilton Award in 2007 and is the author/co-author of 115 publications (67 peer-reviewed) and co-inventor of two US patents. Dr. Ashley received his Ph.D. in Chemistry from the University of Utah. He also holds a M.S. in Chemistry from Northern Arizona University and a B.S. in Biology from the University of Arizona.

Rebecca Lankey Blackmon, P.D. was a 1999-2001 AAAS EPA Fellow in OPPT/Industrial Chemistry Branch and a 2001-2002 ASME White House Fellow at the Office of Science & Technology Policy. Since 2003 Dr. Blackmon has worked as a Subject Matter Expert for the Technical Support Working Group in the Chemical, Biological, Radiological, and Nuclear Countermeasures subgroup. Dr. Blackmon's background is in engineering, with a Ph.D. in Civil & Environmental Engineering from Carnegie Mellon University, an M.S. in Materials Science & Engineering, and a B.S. in Mechanical Engineering.

Michael J. Brisson, M.S. has 30 years of analytical chemistry experience, including 20 years at the Department of Energy's Savannah River Site. Brisson's primary activities include technical support for sampling and analysis of beryllium and other metal particulates within DOE, and design of new analytical laboratories for industrial hygiene and nuclear applications. Brisson has been actively involved in development and improvement of voluntary consensus standard methods for sampling and analysis of workplace atmospheres, as well as development of performance criteria for real-time beryllium monitoring equipment. Brisson's current positions include chairman of the DOE/DOD Beryllium Health and Safety Committee; member of AlliA's Sampling and Laboratory Analysis Committee; Secretary of ASTM International Committee D22 on Air Quality; and U. S. delegate to ISO Technical Committee 146, Subcommittee 2 on Workplace Air.

Morgan Cox is a Certified Health Physicist serving as a senior consultant for the development of radiation detection standards for the Department of Homeland Security. He has over forty years of experience in health physics including operational practice, research and development, sales, marketing and servicing of radiation detection instrumentation. He has been involved in the development of radiation detection instrumentation standards for thirty five years for the American National Standards Institution (ANSI), and for over 20 years for the International Electrotechnical Commission (IEC). He is now the chairman of the IEC Technical Committee 45 for nuclear instrumentation, for nuclear reactor instrumentation and controls (I&C), for radiation protection for workers, the environment and the public, and for safeguarding special nuclear materials in all locations. He is also the co-chair of ANSI N42 subcommittees for Radiation Protection Instrumentation (RPI) and for Homeland Security Instrumentation (HSI). He has been a member of management for each of his employers including Westinghouse Electric, Harshaw Chemical, Victoreen Instruments and Eberline Instruments. He is a Fellow in the Health Physics Society.

John J. Earshen is an Acoustical Consulting Engineer and President of Angevine Acoustical Consultants, Inc. He is a graduate of the Massachusetts Institute of Technology and the State University of New York at Buffalo. Formerly he was Chief Scientist of Metrosonics, Inc., a firm that pioneered development of microprocessor based noise dosimeters. He was formerly Adjunct Professor at the University of Toronto; and Lecturer in Electrical Engineering at the University of Buffalo. At present he is Adjunct Professor at the Hearing Research Laboratory of the State University of New York at Buffalo. He is an active participant in acoustical standard formulation for the American National Standards Institute and is a Fellow of the Acoustical Society of America.

Peter Görner, Ph.D. was born in Czechoslovakia in 1950. He studied Chemical Engineering at the Technical University of Bratislava and received his Ph.D. in Physical Chemistry from Charles University of Prague. Since then, he has been involved in aerosol research. Dr. Görner was employed at the French National Coal Board Research Centre in Paris and from 1987 at National Research Institute on Occupational Safety and Health in Nancy, France. Since 2006, he has been head of the Laboratory of Aerosol Metrology. His current research interest is aerosol, bio-aerosol and nanoparticle sampling, measurement and analysis in the workplace. He is involved in design of some airborne particle samplers and has published several papers on performance of sampling and on direct reading measurement of aerosols.

Richard (Rick) Hansen, B.S. is a senior scientist in the Counter Terrorism Operations Support Program (CTOS) at the U.S. Department of Energy (DOE), National Nuclear Security Administration's (NNSA), Nevada Test Site (NTS). His primary role is supporting curriculum development in the areas of Radiological/Nuclear Weapons of Mass Destruction (WMD), nuclear radiation measurements, radiological emergency response operations, and performance-based training. Rick develops training courses to provide state and local first responders the capabilities to prevent WMD use and to respond to WMD events, under the training programs funded by the Federal Emergency Management Agency (FEMA) National Preparedness Directorate (NPD) and the U.S. Department of Homeland Security (DHS) Domestic Nuclear Detection Office (DNDO). Rick has been a scientist with the current NTS contractor (NSTec) and the previous NTS contractors (Bechtel Nevada - Lockheed Martin Nevada Technologies and EG&G Energy Measurements) since 1989. Prior to joining the CTOS Program, Rick was a DOE radiological nuclear emergency response team scientist tasked with research, development, and technical integration of sensors, computer algorithms, instruments (hand-held, vehicle-mounted, and fixed-facility), and field techniques for locating, identifying, and analyzing hidden nuclear material and environmental radioactive contamination. Rick is also Adjunct Faculty for Counter Terrorism Operations Support at the University of Nevada Las Vegas. Rick received his BS in Engineering Physics (1988) from the University of the Pacific.

Martin Harper, Ph.D. has been Chief of the Exposure Assessment Branch of the Health Effects Laboratory Division, National Institute for Occupational Safety and Health (NIOSH) since 2002. He is a Chartered Chemist by the Royal Society of Chemistry and Certified in the chemical aspects of Industrial Hygiene. His education includes degrees and diplomas in geology, analytical chemistry, pollution control, and environmental science. He was awarded his PhD from the London School of Hygiene and Tropical Medicine for research into air sampling methods development. He worked for a leading manufacturer of air sampling instruments (SKC, Inc.) for eleven years, leaving as Research Director for sampling media products. Dr. Harper taught for three years in the industrial hygiene program at the University of Alabama at Birmingham, and currently holds an adjunct post at West Virginia University and also teaches at the University of the West Indies. Dr. Harper has over 50 peer-reviewed publications, including articles in the Encyclopedias of Analytical Science, Analytical Chemistry, and Separation Science. He has served on many technical committees concerning air monitoring, receiving six awards for his work with the AIHA and ASTM. He served six years as Chair of the ISO TC146/SC2 subcommittee on workplace air quality, and five years as an Editorial Board member for Journal of Environmental Monitoring. He has organized and chaired several international conferences on air sampling and analysis. His interests include sampling and analysis of aerosols, including wood dusts, metals, metalworking fluids, fibers (including asbestos), silica and nanoparticles; active and diffusive gas and vapor sampling; indoor air chemistry; quality assurance of measurements; and exposure assessment strategies and models.

William Heitbrink, Ph.D. has been certified in the comprehensive practice of industrial hygiene since 1978. Since 2001, he is an Associate Professor in the Department Of Occupational and Environmental Health at the University of Iowa. Recent research project have all involved direct reading instruments to measure worker air contaminant exposure. These projects have included characterizing emission sources during final processes at vehicle assembly plant, concentration mapping in a foundry and an engine plant, and crystalline silica exposures during wet abrasive blasting and mortar removal. In 2001, he retired Public Health Service Officer with 30 years of research experience with the National Institute of Occupational Safety and Health (NIOSH). During his career at NIOSH, he conducted research on air sampling methods and the control of air contaminant exposures. The control measures research involved using instruments to study the relationship between process variables and air contaminant exposures. At the end of his Public Health Service career Dr. Heitbrink was awarded the Public Health Service's Meritorious Service Medal for his career achievements, the second highest honor a PHS officer can receive. He has also received awards from technical committees of the American Industrial Hygiene Association for published papers on aerosol science and air contaminant control. Among his professional activities that directly address control of occupational hazards is his membership on the following external committees: the American Industrial Hygiene Association's Engineering Committee, the American Society of Agricultural Engineering's Committee PM03-16 (Environmental Enclosures), and the Iowa Occupational Safety and Health Advisory Council.

Mark D. Hoover, PhD, CHP, CIH is a senior research physical scientist in the Division of Respiratory Disease Studies at the CDC's National Institute for Occupational Safety and Health, in Morgantown, West Virginia. He has a BS degree in mathematics and English from Carnegie Mellon University and MS and PhD degrees in nuclear engineering from the University of New Mexico. He is also board certified in the comprehensive practice of health physics and board certified in the comprehensive practice of industrial hygiene. Dr. Hoover joined NIOSH in 2001 after 25 year's of basic and applied research at Lovelace Respiratory Research Institute in Albuquerque, New Mexico. His career research and practice interests are in protecting workers and the public from respiratory disease by establishing a technical basis for anticipating, measuring, modeling, and mitigating toxic aerosols in the workplace and the environment. His special concerns have focused on aerosols of beryllium, toxic chemicals, fibers, bioaerosols, plutonium, uranium, terrorist acts, and nanotechnology. He has served as an aerosol scientist and principle investigator for many multidisciplinary studies on respiratory health and safety and has developed improved approaches, techniques, and instrumentation for exposure assessment and for aerosol characterization, generation, and control. Dr. Hoover has been a chairman or contributor to the development of many national and international standards, and is author or co-author of more than 150 open literature publications.

Cynthia Jones, Ph.D. serves as the U.S. Nuclear Regulatory Commission's Senior Technical Advisor for Nuclear Security, where she is responsible for providing technical and policy advice for operational initiatives associated with nuclear security, safeguards, and radiological protection. Dr. Jones' has participated in international efforts with the International Atomic Energy Agency, the Nuclear Energy Agency, and as has published over 95 publications, reports, or speeches in the fields of nuclear science, radiological protection, and environmental engineering. Dr. Jones has a Ph.D. and an M.S. in Nuclear Engineering, a second M.S. degree in Health Physics, and a B.A. degree in Physics.

Dean R. Lillquist, Ph.D., MSPH, CIH is the Director of the USDOL/OSHA Salt Lake Technical Center (SLTC). The SLTC performs OSHA's analytical analysis and sampling and analytical methods development, as well as houses OSHA's Health Response Team, which provides technical and investigative support to the Agency. Prior to OSHA, Dr. Lillquist was Associate Professor and Director of the Industrial Hygiene Graduate Program at the Rocky Mountain Center for Occupational and Environmental Health at the University of Utah. He obtained his Ph.D. degree in Environmental Health from Colorado State University where he focused on industrial hygiene and industrial toxicology. He received his MSPH from the University of Minnesota, School of Public Health. Dr. Lillquist is the current President of the Foundation for Occupational Health and Safety (FOHS).

Brian Lowe, Ph.D, CPE is a Research Industrial Engineer with the Division of Applied Research and Technology at NIOSH in Cincinnati, Ohio. He has conducted research at NIOSH since 1998 mostly focusing on the assessment of exposure to risk factors for musculoskeletal disorders of the upper limbs. His research interests include the development and application of practical systems for quantifying hand coupling force. His work has been published in several journals, including Ergonomics, Applied Ergonomics, International Journal of Industrial Ergonomics, Human Factors and Ergonomics in Manufacturing, Medicine and Science in Sports and Exercise, Journal of Occupational Rehabilitation, and Journal of Occupational and Environmental Hygiene.

Dr. Lowe serves on the editorial board of Applied Ergonomics and has served as a reviewer for numerous professional and scientific journals. He holds an adjunct faculty appointment (Associate Professor) in the Department of Environmental Health at the University of Cincinnati. Dr. Lowe received a B.S. degree from Penn State University, a M.S. in Industrial and Systems Engineering from Virginia Tech, and a Ph.D. in Industrial Engineering from Penn State. He is a Certified Professional Ergonomist.

Mark L. Maiello, Ph.D. holds a bachelor's degree in physics from Manhattan College. He started his environmental health science career at New York University with a master's degree investigation of low energy X-ray emission from cathode ray tubes and a doctoral dissertation on the development of a themoluminescent dosimeter-based radon gas detector that was awarded a patent shared with his thesis advisor, Dr. Naomi Harley. In 1986, he joined the U.S. Department of Energy (DOE) at the Environmental Measurements Laboratory in New Yark City performing natural background radiation measurements and quality assessment testing of thermo luminescent dosimeters. Dr. Maiello later joined CoPhysics Corporation, a radiological consulting firm specializing in decommissioning and decontamination of academic and industrial facilities. He has published both peer-reviewed and nontechnical papers on various topics concerning health physics and nuclear weapons. His work has appeared in Radiation Protection Dosimetry, Health Physics, Nuclear News, the on-line journal Weapons of Mass Destruction Insights, and in Health Physics News where he is a contributing editor. Mark is co-editor of the forthcoming book Radioactive Air Sampling Methods (the other co-editor is Dr. Mark Hoover of NIOSH) and contributed to The Aerosols Handbook, both from CRC Press. He has been a guest lecturer in radiation safety at New York University and the New Jersey Institute of Technology. Mark is presently employed as a radiation safety officer at the Pearl River, New York facility of Wyeth Research, a major pharmaceutical research and development company.

Matthew Magnuson, Ph.D. received his doctorate in chemistry in 1994, and performs environmental and analytical chemistry research for several Homeland Security applications, including field and online detection of water contamination. Involved with Homeland Security activities since 2001, he has coauthored over fifty water quality and water security publications, in journals as such Environmental Science & Technology, Analytical Chemistry, and Journal of the American Society for Mass Spectrometry. These activities have included the application of direct reading instruments. For instance, he served on the assessment panel of the Department of Homeland Security's All Hazard Receipt Facility (ARHF), which utilizes direct reading instruments for prescreening unknown and potentially hazardous samples collected under unusual or suspicious circumstances. Another example is that he developed and presented training for site characterization activities for the Water Security Initiative, EPA's response to Homeland Security Presidential Directive (HSPD) Number 9. The audience for the training is laboratory and field personnel, as well as emergency responders. This training includes personnel safety, application of field instrumentation for chemical, biological, and radiological hazards, sample collection and analysis, and handling to preserve the evidentiary qualities of samples. One component of this training is a workshop, focused on the application of Hazmat equipment and appropriate interpretation of the resulting data. This equipment ranges from colorimetric techniques to sophisticated field analytical instruments, such as ion mobility and mass spectrometers.

David Mark, Ph.D. has just retired as Head of Exposure Control and Measurement Section at the Health and Safety Laboratory (HSL), Buxton, UK. He is a physicist who has spent the last 38 yrs carrying out research into the measurement and control of aerosols mainly in workplace, but also in ambient environments. His interest in direct reading dust monitors derives from studies when working for the UK National Coal Board on the development and testing of instruments (mainly light scattering) for evaluating the efficiency of respirable dust control measures deployed underground in coalmines. It continued with measurement of exposure to ambient air pollutants, both indoors and outdoors, the assessment of particulate exhaust emissions from diesel and gasoline powered vehicles, and currently involves studies on the measurement of exposure to airborne nanoparticles in workplaces. He represents the UK on a number of international standards committees and will present the work currently being carried out by CEN/TC 137/WG3 to produce guidance on the use of direct reading aerosol monitors in work places.

Raymond W. McGorry MSBE, PT, CPE has been a senior research scientist with the Liberty Mutual Research Institute for Safety since 1993. He conducts laboratory and field investigations of work related injury and illness and is a regular collaborator on ergonomic studies with other investigators. His research interests include developing work measurement instrumentation, biomechanics, exposure assessment, force measurement during hand tool use, and investigating approaches to musculoskeletal rehabilitation. Prior to joining the Research Institute, Mr. McGorry worked as a physical therapist and as a biomedical engineer.

A recipient of three patents related to measurement of human performance and movement, he has also served as a reviewer of field-initiated research proposals for the National Institutes of Health and National Institute for Disabilities and Rehabilitation Research (NIDRR). He is a reviewer for several professional and scientific journals, and has published in Ergonomics, Applied Ergonomics, International Journal of Industrial Ergonomics, Spine, Journal of Spinal Disorders, Journal of Occupational Rehabilitation, and the Journal of Occupational and Environmental Hygiene. Mr. McGorry holds a B.S. in biology from Villanova University, a graduate certificate in physical therapy from Emory University, and an M.S. in bioengineering from Clemson University. He also completed a post-graduate fellowship in rehabilitation engineering at the Massachusetts Institute of Technology.

John Meeker, SeD, MS, CIH is an assistant professor in the Department of Environmental Health Sciences at the University of Michigan School of Public Health where he teaches graduate level courses in environmental health, exposure science and industrial hygiene. His research interests involve exposure science, reproductive and developmental epidemiology, and assessing exposure and engineering controls in construction.

Jayne B. Morrow, Ph.D. has focused her research to the study of bacterial surface interaction and the implications on fate and transport. Her undergraduate degree is in Civil Engineering from Montana State University where she was an undergraduate research fellow at the Center for Biofilm Engineering. Her M.S. and Ph.D. are both in Environmental Engineering from the University of Connecticut where she studied the fate of pathogenic bacteria and plasmid borne resistance mechanisms in environmental systems. More recently during her tenure at NIST, her research has focused on sampling issues relative to the decontamination of buildings after a bioterror event. Over the last three years, she have been investigating the fate of Bacillus spores in water distribution systems and developing decontamination strategies in a project that was partially funded by the EPA National Homeland Security Research Center in Cincinnati. Part of this work has focused on developing an accurate model of water distribution systems that incorporates biofilm formation by organisms native to the water system and how those biofilms impact the susceptibility of contaminant spores to disinfection. Currently, she is studying the impact of surface properties on aggregation and surface adhesion of Bacillus anthracis Sterne spores and other potential pathogenic bacteria. She has embarked on a Validated Surface Sampling Project that is funded by the Department of Homeland Security to address available methods for the sampling of biological agents on nonporous surfaces and to develop a standard method to evaluate wipe efficiency for the sampling of Bacillus spores on nonporous surfaces before and after building decontamination. This research focuses on determining optimum strategies for the sampling and removal of non-visible spore contamination from surfaces commonly found in industrial and residential settings after a bioterror incident.

Terri A. Pearce, Ph.D. is a Senior Service Fellow in the Laboratory Research Branch of the Division of Respiratory Disease Studies at the National Institute for Occupational Safety and Health (NIOSH). Dr. Pearce received both a Ph.D. in Industrial Hygiene and a Master's degree in Industrial Hygiene and Environmental Management from the University of Oklahoma Health Sciences Center. Prior to joining NIOSH, Dr. Pearce was in private industrial hygiene practice. Her NIOSH research projects focus upon aerosol exposure assessment with particular emphasis on use and validation of direct-reading instruments for characterizing workplace exposures.

Michael Phillips, MD, FACP is the founder and chief executive officer of Menssana Research, Inc. a firm specializing in developing non-invasive methods for disease detection. Menssana Research has developed a portable breath collection apparatus (BCA) which is currently undergoing clinical studies to evaluate breath testing in several diseases including lung cancer, breast cancer, heart transplant rejection, ischemic heart disease, kidney disease and diabetes mellitus. The Food and Drug Administration has approved the breath test for heart transplant rejection for clinical use. Dr. Phillips is also a Professor of Clinical Medicine at New York Medical College, Valhalla, NY.

Robert G. Radwin, PhD is Professor and founding Chair of the Department of Biomedical Engineering at the University of Wisconsin. He also holds academic appointments in the Department of Industrial and Systems Engineering in the College of Engineering, and in the Department of Orthopedics and Rehabilitation in the Medical School. He actively studies the recognition, causes and control of musculoskeletal disorders in manual work. His research is concerned with developing measurement and analytical methods for assessing exposure to physical stress in the workplace; understanding ergonomics aspects of the design, selection, installation and use of manually operated equipment including hand tools; and quantifying functional deficits associated with musculoskeletal disorders and peripheral neuropathies. He is frequently a consultant to industry and government agencies for his expertise in industrial health and ergonomics in manufacturing and product design. Dr. Radwin is a Fellow of the American Institute of Medical and Biological Engineers, the Biomedical Engineering Society, the Human Factors and Ergonomics Society (US), and the Ergonomics Society (UK). He is a member of the NIOSH Study Section and the Association for the Advancement of Medical Instrumentation Human Factors Engineering Committee (HE75 Draft Standard for Human Factors Design of Medical Devices).

Stephen M. Rappaport, Ph.D. received his B.S. degree in Chemistry from the University of Illinois in 1969 and his Ph.D. in Environmental Sciences and Engineering from the University of North Carolina in 1973. Between 1976 and 1990 he was Professor of Environmental Health at the University of California, Berkeley. He left Berkeley in 1990 to join the faculty of the University of North Carolina, and, in 2006, he returned to his former position at Berkeley. Professor Rappaport is Principal Investigator of the new NIH-funded Center for Biological Response Indicators of Environmental Stress, a multidisciplinary program project that brings together Berkeley researchers from Public Health, Chemistry, and Electrical Engineering to develop a new generation of biomarkers and biosensors. He is a pioneer in the emerging field of 'Exposure Biology', and much of his current research involves development and application of biomarkers of exposure to toxic chemicals, including benzene and polycyclic aromatic hydrocarbons. He uses environmental measurements and biomarkers to elucidate the metabolism of these substances in exposed subjects and to quantify interindividual variability in biomarker levels due to genetic, environmental and lifestyle factors. Prof. Rappaport has also published extensively in areas related to the assessment of long-term chemical exposures for purposes of controlling workplace hazards and of investigating exposure-response relationships. He has more than 170 peer-reviewed publications and has collaborated extensively with investigators throughout the world.

Mark Spence, MS received BS and MS degrees in chemistry from Clarkson University and Michigan State University, respectively. Mark has worked in Environment, Health and Safety at the Dow Chemical Company in Midland, Michigan for the last 30 years. Following an initial assignment in environmental toxicology, the majority of Mark's Dow career has been in various industrial hygiene roles. A Certified Industrial Hygienist, his areas of specialty include respiratory protection & personal protective equipment, and industrial hygiene exposure monitoring. Mark is currently a member of Dow's EH&S Regulatory Affairs, where he serves as Dow's Manager of Health & Safety Regulatory Affairs.

Pam Susi, MS serves as the Exposure Assessment Program Director for CPWR - the Center for Construction Research and Training (formerly the Center to Protect Workers Rights) - a research and training arm of the Building and Construction Trades Department, AFL-CIO. She received a Masters of Science in Public Health in Air and Industrial Hygiene at the University of North Carolina at Chapel Hill in 1991. Ms. Susi began working at CPWR in 1993 and has since been active in developing new exposure assessment strategies for construction - a particularly challenging industry for industrial hygienists. She has co-chaired with NIOSH, the CPWR/NIOSH Engineering and Work Practice Controls Workgroup since 1994. Ms Susi has been a member of the Carpenters Union for over 25 years and has worked in construction since 1981, as a carpenter until 1988 and as an industrial hygienist since 1991.

Charles Timchalk, Ph.D. received a B. S. in Biology from the State University of New York, and a Ph.D. from the Department of Pharmacology and Toxicology, The Albany Medical College. He joined the Dow Chemical Company as a post-doctoral fellow within the Biotransformation and Molecular Toxicology Group of the Toxicology Research Laboratory. At Dow he was a Research and Technical Leader within the Pharmacokinetics and Metabolism group prior to accepting his current position. He is currently a Staff Scientist within the Center for Biological Monitoring and Modeling at the Pacific Northwest National Laboratory. In this position he is continuing to pursue his interest in the application of pharmacokinetics for evaluation of human health risk. His research is currently focused around 3 themes: 1) the development of new technologies and approaches for non-invasive biological monitoring. 2) Advancing pharmacokinetic and pharmacodynamic modeling to focus on the assessment of risk to potentially sensitive populations, such as children, and to evaluate the health risk implications of low dose chemical mixture exposure. 3) The utilization of advanced imaging and 3dimensional modeling approaches to develop new dosimetry and biological response models.

Jon C. Volkwein, M.S. has over 30 years of experience in the mining research field -- initially with the Bureau of Mines and now at NIOSH. His research has covered areas of dust measurement and control in silica processing, coal mine ventilation, methane control, coal mine productivity, inert gas protection of high wall mining systems, applications of biotechnology to mining, and currently -- improved dust monitoring for mining. His research has taken him into well over 100 different mines and mills throughout the U. S. and has resulted in over 180 papers and presentations of the work. Mr. Volkwein has a BS in Chemistry and an MS in Biology from the University of Pittsburgh. He is a co-recipient of a 2004 R&D 100 Award for his work on the Personal Dust Monitor.

Peng-Yau Wang, Sc.D. is an Associate Professor at the Graduate Institute of Environmental Engineering at National Central University, ChungLi, Taiwan. His research interest is Dr. Wang completed an Environmental Science Sc.D. at Harvard University in 1997. He previously completed M.S. and S.B. degrees in Environmental Engineering at the National Cheng Kung University, Tainan, Taiwan. Dr. Wang's research interests include real-time monitoring of worker exposure in relation to work activity. He has several research publications as well as four Chinese and three US Patents related to that interest area.

James Weeks, Sc.D. is an industrial hygienist consultant to the United Mine Workers of America. He first became involved in the values of direct-reading instruments for respirable dust in 1978 when the beta-gauge was being considered for use in the coal mining industry. More recently, he was a member of the joint Operator-NIOSH-Union committee on the PDM and helped to develop a common position on its use for presentation to MSHA. He received an engineering degree from the University of California, Berkeley and a ScD in public health from Harvard.

Wassana Yantasee, Ph.D. is Senior Scientist at the Pacific Northwest National Laboratory, operated by Battelle for the U.S. Department of Energy. Yantasee received a B.S. (1995) in Chemical Engineering from Chulalongkom University, Thailand while receiving her M.S. (1999), Ph.D. (2001) in Chemical Engineering, and MBA (2001) from Oregon State University. She specializes in functional nanomaterials for environmental and medical applications. She is a leader in developing portable metal analyzers based on preconcentration of toxic metals using functional silica and magnetic nanoparticles followed by metal detection using voltammetric techniques. She has developed portable sensors for noninvasive biomonitoring of lead, funded by NIEHS. Yantasee is currently the PI of a CDC/NIOSH/R21 project entitled ''Portable Analyzer for On-site Monitoring of Worker Exposure to Toxic Metals", the PI ofNIEHSIR21 project entitled "Novel Chelators for Highly Efficient Removal of Toxic Heavy Metals in Humans", a co-PI of NIH/NIAID/Project BioShield entitled "Selective Nanoporous Sorbent for Radionuclide Decorporation", and a co-I of NIH/NIAID/Project BioShield entitled "Rapid Assay for Internalized Radionuclides with Advanced Materials and Methods Mechanisms, Diagnosis and Treatment of Radiation Injury From a Nuclear Accident or Terrorist Attack". In 2007, she has received Ronald L. Brodzinski Award for Early Career Exceptional Scientific Achievement. Yantasee is a judge for NIEHS (superfund) and DOE/SBIR (subsurface monitoring) proposals. She has 3 patent applications, 6 invention reports, and authored over 35 peer-reviewed papers and three book chapters.

Edward T. Zellers, Ph.D. earned his BA degree in Chemistry from Rutgers University in 1978 and the MS (1984) and PhD (1987) degrees in Environmental Health Sciences from the University of California, Berkeley. From 1978-1981, he worked at Bell Laboratories, Murray Hill, N. J. on the synthesis and characterization of electrically conductive organic materials. He joined the faculty at the University of Michigan in 1987 and is currently a Professor in the Department of Environmental Health Sciences (EHS) and in the Department of Chemistry. Since 1999, he has been the Director of the Industrial Hygiene Program in the EHS Department. Since 2001, he has been the Leader of the Environmental Sensors and Subsystems Thrust in the NSF-funded Engineering Research Center for Wireless Integrated Microsystems (WIMS) at Michigan, where he coordinates an effort to develop a wireless microfabricated gas chromatograph for monitoring complex organic-vapor mixtures in air and biological media. He has been involved in research on chemical micro sensors and micro-instrumentation for over 23 years and has authored/co-authored over 100 publications on these and other topics related to the evaluation of exposures to toxic chemicals.

D.R.E.A.M.
WORKSHOP

Direct-Reading Exposure Assessment Methods Workshop Agenda

Day 1 – November 13, 2008

7:00 – 8:00 A.M.	**Registration**
8:00 – 12:15 P.M.	**General Session** *Christopher Coffey – Moderator* Chief, Laboratory Research Branch Division of Respiratory Disease Studies National Institute for Occupational Safety and Health
8:00 – 8:05 AM	**Welcome** *Christine Branche, PhD* Acting Director National Institute for Occupational Safety and Health
8:05 – 8:10 AM	**Introductory Remarks** *John Howard, MD* Consultant
8:10 – 8:15 AM	**Overview of Workshop** *David Weissman, MD* Director, Division of Respiratory Disease Studies National Institute for Occupational Safety and Health
8:15 – 9:00 AM	**Part I: Radiation detection in the 21st century- Basics, sources, applications and challenges** **Part II: Impact of the Department of Homeland Security on radiation detection** *Morgan Cox* Chairman, IEC TC 45
9:00 – 9:45 AM	**DRMs and what they mean to the worker** *Jon Volkwein* Research Physical Scientist Pittsburgh Research Laboratory National Institute for Occupational Safety and Health *Dennis O'Dell* Administrator for Occupational Health and Safety United Mine Workers of America

Direct-Reading Exposure Assessment Methods Workshop Agenda

D.R.E.A.M. Workshop – Day 1 continued

9:45 – 10:30 AM	**Validation of Direct Reading Methods (and how NOT to validate them)** *Matthew Magnuson, PhD* Research Chemist Environmental Protection Agency
10:30 – 10:45 AM	**~ Break ~**
10:45 – 11:05 AM	**Integration of activity through position** *Peng-Yau (Eric) Wang, PhD* Associate Professor National Central University, Taiwan
11:05 – 11:30 AM	**Experiences with Direct Reading Instruments for Exposure Assessments** *William Heitbrink, PhD* Associate Professor University of Iowa
11:30 – 12:15 PM	**Issues Motivating the Collection of Occupational Exposure Data** *Stephen Rappaport, PhD* Adj. Professor of Environmental Health University of California, Berkeley
12:15 PM – 1:30 PM	**Lunch**

Room assignments will be posted by session
Participants attend one of eight preselected breakout sessions by hazard: (1) Gas and Vapor; (2) Aerosols; (3) Ergonomics and Vibration; (4) Noise; (5) Radiation; (6) Biomonitoring and Surface Sampling

1:30 to 3:00 PM	**Concurrent Breakout Sessions by Hazard** (Each breakout session has developed its own detailed agenda, which is available in the back of this notebook. Times and topics will vary by session.)
3:00 to 3:15 PM	**~ Break ~**
3:15 to 5:00 PM	**Concurrent Breakout Sessions by Hazard**

Direct-Reading Exposure Assessment Methods Workshop Agenda

D.R.E.A.M. Workshop – Day 2 November 14, 2008

7:00 – 8:00 AM **~ Breakfast**

8:00 – 11:30 AM **Full Plenary Session**

Designated Monitors and/or Rapporteurs from each hazard breakout session summarize the top research issues identified. (10 minute presentation/20 minute discussion)

Christopher Coffey – Moderator
Chief, Laboratory Research Branch
Division of Respiratory Disease Studies
National Institute for Occupational Safety and Health

8:00 – 8:30 AM **Gases and Vapors**

Jay Snyder
Physical Scientist
National Personal Protective Technology Laboratory
National Institute for Occupational Safety and Health

Jason Ham
Associate Service Fellow
Health Effects Laboratory Division
National Institute for Occupational Safety and Health

8:30 – 9:00 AM **Aerosols**

Martin Harper, PhD
Chief, Health Effects Laboratory Division
National Institute for Occupational Safety and Health

Terri Pearce, PhD
Senior Service Fellow
Division of Respiratory Disease Studies
National Institute for Occupational Safety and Health

9:00 – 9:30 AM **Ergonomics**

Brian Lowe
Industrial Engineer (Research)
Division of Applied Research and Technology
National Institute for Occupational Safety and Health

D.R.E.A.M. Workshop – Day 2 Continued

	Vern Anderson Chief, Information Resources Branch Education and Information Division National Institute for Occupational Safety and Health
9:30 – 10:00 AM	**Noise** *Churci (Chuck) Kardous* Electrical Engineer -Engineer Officer Division of Applied Research and Technology National Institute for Occupational Safety and Health
10:00 – 10:30 AM	**Radiation** *Jeri Anderson, PhD* Health Physicist Division of Surveillance, Hazard Evaluations, and Field Studies National Institute for Occupational Safety and Health
	Mark Hoover, PhD Research Physical Scientist Division of Respiratory Disease Studies National Institute for Occupational Safety and Health
10:30 – 11:00 AM	**Surface Sampling & Biomonitoring** *John Snawder* Research Biological Scientist Division of Applied Research and Technology National Institute for Occupational Safety and Health
	Deborah Sammons Medical Technologist Division of Applied Research and Technology National Institute for Occupational Safety and Health
11:00 – 11:30 AM	**Wrap-up and Closing Remarks**
11:30 AM	**Adjourn the Workshop**

Workshop Description

The workshop gathered stakeholder input from academia, labor, management, governmental agencies, developers, and manufacturers on the research needs in the area of direct reading methods for assessing occupational exposures. The general session included a group of plenary state-of-the-art presentations addressing direct reading exposure assessment methods for workplaces and will cover issues relevant to the broad range of employment sectors and occupational hazards, such as validation, data handling, and interpretation.

Following the general session there were six concurrent breakout sessions divided by hazard, including: aerosols, gases/vapors, ergonomics (including vibration, lighting, and heat stress), noise, ionizing radiation, and surface sampling/biomonitoring. Each breakout session developed the specific research needs for each type of occupational hazard. Input from the workshop helped to develop research priorities for direct reading exposure assessment methods. Proceedings from the workshop are posted on the NIOSH website at: http://www.cdc.gov/niosh/docs/2009-133/.

Learning Outcomes

On completion, the participant was able to:

- Describe important comprehensive and contemporary information about the state-of-the-art/ state-of-the-science regarding real-time assessment of worker exposure
- Determine direct-reading methods for their exposure of interest are available
- Identify gaps in the currently-available technology real-time exposure methods
- Specify agendas for direct-reading method research by occupational agent hazard class

Direct-Reading Exposure Assessment Methods Workshop Meeting Summary

Welcome

Christine Branche, PhD, Acting Director of NIOSH, welcomed the participants and thanked them in advance for their suggestions. Ideas from the workshop will be incorporated into NIOSH research efforts, which address a wide range of activities, including those of first responders. She thanked Christopher Coffey, PhD, and David Weissman, MD, as well as people from a number of NIOSH divisions, for organizing the workshop. She emphasized that the workshop represents important work that will be integrated into NIOSH's efforts.

Introduction

John Howard, MD, former NIOSH Director, set the stage for the workshop, saying he had long anticipated the time when workers could conduct their own exposure assessment in real time. He hoped that all would look at the issue of direct-reading method (DRM) research including from a manufacturing and innovation standpoint by employers, workers, and non-government organizations. Dr. Howard emphasized that success in this arena requires not just technological development but also attention to the culture of the workplace and to regulatory structures. Rapid exposure assessment tools may help individuals identify potential problems on the front lines and implement risk management techniques in real time. Dr. Howard hoped the workshop would identify areas for research and development that would bear fruit for many years to come.

Overview

David Weissman, MD, Director of the Division of Respiratory Disease Studies at NIOSH and manager of the Exposure Assessment NORA cross sector program, explained that guest speakers would describe the state of the art of DRMs in various contexts. Later, participants would break into groups organized by type of exposure to identify key research needs. Each breakout group would summarize its findings during a second general session. Dr. Weissman said the deliberations of the breakout groups would drive the NIOSH research agenda.

Presentation Summaries

Radiation Detection in the 21st Century and the Impact of the Department of Homeland Security (DHS) on Radiation Detection Instrumentation
Morgan Cox, CHP

Mr. Cox described four types of radiation of concern (alpha, beta, photon, and neutron), their primary sources, and current detection technology, methods, and challenges for each. Mr. Cox sees great potential in the use of long-range alpha detection, which can measure alpha contamination from irregular surfaces, tubing, and piping. New methodologies for photon radiation detection are emerging with new detector types.

The International Atomic Energy Agency is seeking improved neutron detectors, primarily to detect illegal trafficking of nuclear materials across borders. The U.S. Army has tested the Stanley Kronenberg carbon fiber detector, which uses two coupled ion chambers to detect neutron radiation. Researcher Mario Overhoff demonstrated that coupling a scintillator with a photomultiplier tube can measure fast neutrons at low levels. To date, no commercial entity has explored development of either technique.

Mr. Cox noted that the creation of the DHS and the threat of so-called dirty bombs led to the rapid development of new standards for radiation detection and new, stringent DHS testing and evaluation protocols. The new standards sparked demand for new technology, and DHS tied some funding requirements for procurement of radiation detectors to the standards. The emphasis of DHS has been on radiation detection, not protection. The agency identified some specific needs in terms of product development, which has stimulated some technological advancements (e.g., miniaturization, improved portability). However, much more work is needed, and the DHS is seeking more experts willing to assist in development of standards.

Discussion

Mr. Cox described the American National Standards Institute (ANSI) standards N42.49 A & B, which address personal emergency radiation detectors with and without alarms. These standards were written with input from potential users (e.g., fire protection workers, law enforcement officers) and manufacturers, which highlighted some areas of tension between what users want and what manufacturers can provide.

Mr. Cox acknowledged that more research is needed to better understand the wide range of individual responses to radiation exposure. He noted that healthy, young people may be able to withstand higher doses or more exposure than others and that women appear to be more resistant to radiation exposure, although researchers do not know why. More attention to biodosimetry in radiation detection may offer some insight on the linear threshold of radiation damage.

Selection of DRMs and What They Mean to the Worker
Jon Volkwein, NIOSH

Mr. Volkwein observed that periodic assessment of hazards in the workplace is effective for stable work environments, but miners, among others, face constantly changing work environments. He summarized five key areas to address in development of DRMs: continuous monitoring, frequency of sampling, worker involvement and education, verification of exposure, and innovation. Current DRMs have great value in identifying sources of exposure but require skill to understand and interpret. Ideally, DRMs will become easier to use yet still provide accurate, unambiguous results. Workers need DRMs that don't impede their ability to do their jobs and provide them enough information to help them manage or reduce exposure or risk.

The higher the hazard threat, the more frequently sampling may be required, which affects the cost of using the DRM. To evaluate the cost-benefit ratio of DRMs, Mr. Volkwein recommended analyzing the return on investment (e.g., using ORC Worldwide's Return on Health, Safety, and Environmental Investments software). He reminded participants that the cost of a citation from the Occupational Safety and Health Administration (OSHA) is an indirect expense that could be avoided by use of DRMs and should be factored into research and cost-benefit analyses, as should potential savings from decreased worker compensation claims and lower health insurance premiums.

The key lesson from the implementation of personal dust monitors among miners was the importance of worker participation. Workers should be involved from the outset in the design of DRMs, and they should be educated on what the device measures, how it works, and what the measurements mean, empowering them to recognize potential hazards early and mitigate their risk. Research on noise exposure has shown that simply having access to real-time data was enough to spur workers to take measures to reduce their exposure.

In response to a question, Mr. Volkwein acknowledged that workers may be motivated to manipulate the results of DRMs so they can continue to work and earn overtime pay, for example. He said rules regarding sampling should be written to minimize the incentives to intentionally over or under-report the results. Furthermore implementation of sampling and/or monitoring rules for individuals should make clear that use of a DRM is not a substitute for engineering controls.

James Weeks, United Mine Workers of America

Mr. Weeks described the history of occupational safety efforts in mining, which underscore many of the concerns mine workers have about the development and use of DRMs. For example, when the Congress passed the Coal Mine Health and Safety Act in 1969, it set standards for respirable dust but gave responsibility for measuring dust levels to the mine operators. Years later, about 200 mine operators were convicted of submitting fraudulent samples to MSHA. Efforts to develop a tamper-proof sampling device were stalled by government deregulation efforts of the 1980s.

In 2000, MSHA proposed rules on employing direct-reading personal dust monitors. Mine workers and operators united in their opposition to the rules and came to consensus on the following points:

- MSHA should be responsible for obtaining samples to determine compliance.
- Only one device, the personal dust monitor, should be used to monitor exposures to determine compliance (instead of allowing mines to choose from among several devices).
- Sampling information should be available to all interested parties.
- Samples should be taken over a full shift (often as long as 12 hours) and the results averaged over a work week (normalized to 40 hours) to better represent real-life scenarios.
- MSHA should not calculate a margin of error for purposes of determining non-compliance standards should include fixed limits, above which a citation is given.

Validation of DRMs (and How Not To Validate Them)
Matthew Magnuson, PhD, Environmental Protection Agency (EPA)

EPA's National Homeland Security Research Center (http://www.epa.gov/nhsrc/) evaluates DRMs to provide reliable information regarding the performance of homeland security related technologies. Testing is performed to generate objective performance data so building and facility managers, first responders, groups responsible for building decontamination, and other technology buyers and users can make informed purchase and application decisions.

Performance characteristics of DRM should be validated, and establishing performance criteria is challenging. A handful of performance standards for DRM are identified within the DHS Standards Database, mostly for radiation and toxic gases. Accordingly, third-party testing is an important component of evaluating performance to provide potential users with unbiased information that can supplement vendor-provided information in areas such as DRM performance, comparability of DRMs from different manufacturers, or use of a DRMs in various settings. The EPA's Technology Testing and Evaluation Program (TTEP, http://www.epa.gov/nhsrc/ttep.html) evaluates both commercially available technology and products still in the development stage, either supplied by manufacturers or purchased by EPA. TTEP rigorously tests technologies against a wide range of performance characteristics, requirements, and/or specifications. The program includes peer review, input on product design from stakeholders, and review of the project plans as well as the test results.

EPA and others focus on the relevance of the data provided by DRMs. In the field, information from DRMs should be unambiguous and interpretable by the operator. Training that addresses using the DRM and interpreting the resulting data is key. Such training must be specific to the needs of the worker and conducted in advance of using the DRM.

At present, the field of validation requires more high-level, scientifically derived assessments of performance characteristics that apply to the specific purpose of the DRM. From a policy perspective, validation should link performance, testing, and operational standards to funding mechanisms and ensure that operator integration (e.g., training and real-world assessment) is part of the validation process. Manufacturers need a mechanism for showing how an instrument works and for seeking validation that does not compromise the confidentiality of its research and development efforts. Government policy can play a role in helping manufacturers see novel potential markets for their equipment.

Discussion

A participant said he'd like to see NIOSH take up testing and validation, as it has in the past. He added that requiring manufacturers to test and validate their products at their own expense poses significant barriers unless all manufacturers are required to validate products in the same way.

Another participant asked whether EPA has guidelines or standards on performance characteristics. Dr. Magnuson responded that testing evaluates what a product can do and users decide whether those functions suit their needs. Other EPA efforts focus on setting target goals, for example, for environmental cleanup. However, states can set their own target goals, so manufacturers are challenged to develop products that can meet several states' standards.

Integration of Activity Through Position
Peng-Yau Wang, PhD, National Central University, Taiwan

Dr. Wang described the shortcomings of some existing techniques for monitoring worker activity and exposure, such as questionnaires, daily records, and video analysis. To improve understanding of what workers are doing at any given time and how that relates to exposure, his company, Sweetek, Inc., is developing a location tracking device that can be used indoors and coupled with sensors to provide real-time data. It uses the same technology as wireless computers, and information can be relayed instantly from the field to a computer server.

By adding small, portable, easy-to-use relay devices, the tracking device can function in confined spaces and remote areas. Data can be displayed in the field in real time. The device could have a wide range of applications. Dr. Wang's company is incorporating it into a sleep study to assess body position in relation to sleep disorders.

Dr. Wang emphasized the importance—and the difficulty—of limiting the information collected to avoid being overwhelmed by data. Also, worker safety must be weighed against privacy concerns. Dr. Wang's company created a protocol for ensuring that workers agree to release the data collected on them, but regulations in this area are needed.

DRMs as Tools for Industrial Hygiene Troubleshooting and Exposure Assessment
William Heitbrink, PhD, University of Iowa

Dr. Heitbrink explained some of the inherent drawbacks of current DRMs, noting that more data are needed that reflect real-world situations. While it's difficult to rely on instruments to provide accurate data, they are useful in measuring relative concentrations (e.g., to determine high vs. low exposure). In addition, instruments are needed that can provide good resolution in a very short time to better assess exposure for a task that takes only a few seconds. Data analysis can be frustrated by autocorrelation—that is, current readings may be a function of past measurements. Furthermore, a given DRM may not take into account all the variables, such as wind direction or the decline in function of a vacuum as the collection bag gets full. In addition, instruments do not provide feedback that relates directly to the association between exposures and health outcomes. While current technology has its uses, Dr. Heitbrink said we lack statistical data of sufficient quality to improve decision making or standard setting.

Dr. Heitbrink described the use of space concentration mapping using an optical particle counter in an auto engine manufacturing plant to illustrate his concerns. While the approach helped identify areas where the manufacturer could improve air quality in the plant, most of the data collected were too variable and unreliable to use as a basis for statistical analysis.

How to Collect DRM Data Based on Use
Stephen Rappaport, PhD, University of California, Berkeley

Even current collection methods result in data that have an enormous range of variability, said Dr. Rappaport. Even a single worker's exposure can vary markedly in relation to the type of work performed; the duration of that work; day-to-day differences in type, location, and duration of work and equipment used; and environmental changes. To determine cause and effect, analysis must sort out the influence of numerous variables, which requires a lot of data. With sufficient amounts of data, statistical models can be applied that account for both fixed and variable determinants.

Dr. Rappaport underscored the two distinct purposes for collecting exposure data: 1) to identify and control potential hazards and 2) to survey the health effects of exposure. For health surveillance that focuses on the chronic health effects of long-term exposure, researchers need longitudinal studies that evaluate the variations between individuals and their circumstances. Hazard control that focuses only on short-term exposure hazards only requires information on the amount of toxic material in a specific environment. In the United States, industries have focused on short-term hazard control. The government established compliance testing that relies almost entirely on voluntary assessments made by the employers themselves, which minimizes incentive to take frequent samples or collect large amounts of data. Given the current state of affairs, Dr. Rappaport said, it is unlikely that we will collect sufficient data to address long-term health effects of exposure.

Dr. Rappaport cited the European Union's 2006 regulation, Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), as an example of a system designed to evaluate the long-term health effects of chemical exposures. Devices exist to collect and evaluate exposure data, but the United States must better enforce its regulations so that data can be used more effectively.

Reports and Recommendations by Hazard

Each breakout group was charged with identifying five top research priorities. All of the breakout groups determined that research should seek to develop new or refined technologies that meet sector-specific DRM needs, and several addressed the question of how to encourage product development for niche markets. Other recurring themes emerged from the breakout group reports:

- Worker empowerment involves educating and training users to better understand how specific DRMs work, what the DRMs can and cannot do, and how to interpret the data from their DRMs.
- In nearly every setting, standards are needed to ensure the accuracy of DRMs and to validate their performance.
- Efforts are needed to speed the transition from research to real-world application of DRMs.
- The criteria for exposure must be re-evaluated or defined in several sectors.

Gases and Vapors
Monitors: Jay Snyder, NIOSH; Ted Zellers, PhD, University of Michigan
Rapporteur: Jason Ham, PhD, NIOSH

The breakout group identified nine research priorities. Mr. Ham explained the group's rationale for each.

Research Priorities

1. Pursue gas chromatography miniaturization, which could be coupled with other detectors, sensor arrays, or mass spectrometry, for example, to identify one compound within a mixture.
2. Explore techniques that allow workers to measure their own exposures. To accrue more data, evaluate options that are simple, cheap, and provide high throughput. Some accuracy may be sacrificed to provide more raw data.
3. Refine existing technologies and improve their sensitivity and selectivity, e.g., for detecting toxic gases, hydrogen sulfide, and carbon monoxide.
4. Make devices multi-functional, e.g., capable of recording chemicals present, temperature, and heart rate and incorporating global positioning systems.
5. Develop self-calibrated systems, eliminating the need for gas transport.
6. Focus on "niche" DRMs, e.g., for formaldehyde, hafnium, chloramines (for the poultry industry), nicotine, and organic isocyanates. Explore how NIOSH can contribute to development of DRMs with narrow market applications and that are unlikely to be commercially successful.
7. Establish NIOSH-OSHA collaboration to transition new DRMs to compliance-acceptable status.
8. Develop DRMs for unknown chemical components in mixtures.
9. Seek methods for worker empowerment, e.g., DRMs that give feedback directly to workers, thus giving them options to modify their behavior or environment.

Discussion

Moderators clarified that, because more data are needed overall, DRMs that provide data of less-than-perfect accuracy may be acceptable. One participant suggested that NIOSH set standards for the level of accuracy that is acceptable for field readings (as opposed to laboratory research or compliance assessment). Dr. Zellers agreed, noting that OSHA does include some standards for DRMs and that OSHA will assist with validation and, potentially, marketing when promising technologies emerge.

Much discussion surrounded the concepts of worker empowerment and behavior modification. Many agreed on the value of immediate feedback to enable the worker to modify his or her environment. Some pointed out that workers need training and knowledge to adapt to or modify their work environments or work processes. One person stressed the need for DRM operators to understand fully how a given device works, what it can do, and what it can't do.

A participant asked why existing hydrogen sulfide and carbon monoxide monitoring technologies need further refinement. An oil refinery employee responded that he regularly hears complaints about false alarms, wide ranges of measurements, interfering components, and other issues that compromise the performance of DRMs for these substances.

The breakout group recommended that manufacturers seek to add more functions to their devices to make them more useful in broader markets. While some argued that developing more complex devices moves focus away from the need for simple, inexpensive tools, Dr. Zellers pointed out that the market for DRMs for gases and vapors is so small that even manufacturers of good tools have gone out of business because the market is so limited.

Aerosols
Monitors: Martin Harper, PhD, NIOSH; Pam Susi, CPWR—Center for Construction Research and Training
Rapporteur: Terri Pearce, PhD, NIOSH

Research Priorities

1. Conduct basic research on how instruments respond to different aerosol characteristics.
2. Invent/continue development of aerosol monitors, especially agent-specific monitors (not just dust).
3. Develop consensus standards on accuracy and validation with input from manufacturers, OSHA, and other stakeholders. NIOSH should not be responsible for validating instruments.
4. Develop standards for performance and use of monitors.
5. Develop sector-specific education and guidance on use of monitors in specific environments.

Discussion

Dr. Harper clarified that NIOSH representatives work with ASTM International (formerly the American Society for Testing and Materials), ANSI, and the International Organization for Standardization (ISO) via technical committees to develop consensus standards. While there is little activity on development of DRM standards in the United States, the European Commission and ISO are developing joint standards (see the European Committee for Standardization's draft technical report, "Guide for the Use of Direct-Reading Instruments for Aerosol Monitoring") that were reviewed by an ISO technical committee on which NIOSH is well represented. A participant added that ASTM is developing a standard that addresses chemical vapor detectors. Kevin Ashley, PhD, of NIOSH said NIOSH is pursuing opportunities to develop standards.

Dr. Harper noted that other than monitoring nano-sized diesel particles, the breakout session did not address nanoparticles. Some European standards on nanoparticles are nearing publication.

In response to a question about whether manufacturers are pursuing agent-specific monitors, Dr. Harper echoed Dr. Zellers in saying that markets are so small that they are not seen as profitable areas for technology development.

Dr. Harper said more basic research on characteristics of aerosols will help manufacturers take into account how instruments respond to particles of different sizes. Dr. Heitbrink called for more attention to how existing instruments can be used in different facilities and settings and emphasized the importance of more sector-specific education and guidance.

Ergonomics
Monitors: Brian Lowe, NIOSH; Rob Radwin, PhD, University of Wisconsin-Madison
Rapporteur: Vern Anderson, NIOSH

Measuring and mitigating ergonomic risk factors that contribute to musculoskeletal disorders poses unique challenges. In ergonomic terms, “exposure” refers to factors such as force, motion, vibration, and temperature. The worker’s interaction with the workplace and tools and the physical demands of the work can present a hazard. Measurement techniques must be indirect, as they must predict the internal load on muscles and joints caused by the interaction. Current assessment of exposure ranges from simple techniques, such as using a worker’s job title as a surrogate on which to base exposure, to use of electromyography to measure muscle activity, accelerometry, force sensors, and video monitoring.

Research Priorities

1. Assess the specific needs of specific customers for DRMs (e.g., researchers, practitioners, workers). The relativity immaturity of the field demands that more basic research be conducted.
2. Develop technologies to measure exposure dose or improve existing technology (e.g., through miniaturization or better usability).
3. Investigate pathophysiological processes associated with exposure (e.g., biomonitoring for tissue response as an indicator of musculoskeletal outcomes).
4. Establish valid exposure assessment criteria. Currently, no exposure limits exist.
5. Translate research into practical instruments for DRMs.

Discussion

Dr. Radwin pointed out that NIOSH and others have developed some ergonomics guidelines that could be relevant for development of DRMs and may include some exposure limits. However, more research is needed. He clarified that laboratories use a number of instruments in research that have not successfully been modified into devices that could be used by workers in the field. Because developing appropriate measurements to determine musculoskeletal exposure is in itself a complex task and because the field of ergonomics is relatively young, development of DRMs for ergonomics is in its infancy.

A participant pointed to the increasing accessibility of accelerometry and added that the entertainment and gaming industries are driving biomechanical research. Another noted that he uses sensors and video motion analysis to evaluate exposure among musicians; in the process, he’s found that the results can help musicians improve their performance. Thus, improving abilities may be an incentive to push ergonomics research ahead.

Dr. Radwin emphasized that the environment or the task usually dictates what the worker must do, and the worker often does not have the option of modifying his exposure. He pointed to a back belt currently on the market that alerts the wearer when he or she is lifting incorrectly. Dr. Radwin said the alarm is simply annoying when the wearer knows that he or she has no choice but to lift incorrectly under the circumstances. While some feedback tools can be helpful for workers, he called for more focus on the design of the workplace and tools that decrease stress on workers.

A participant noted that more advanced technology is needed to integrate the multiple measures needed to assess musculoskeletal exposure. Others added that exposure assessment must take into account real-world variables, such as an individual’s size, strength, and ability and the use of personal protective equipment.

Noise
Monitors: Chuck Kardous, PhD, NIOSH; Rob Brauch, Larson Davis; John J. Earshen, Angevine Acoustical Consultants, Inc.
Rapporteur: Dave Byrne, NIOSH

A number of well developed DRMs for measuring noise exposure exist, and correlating standards have been in place for nearly 30 years. More attention is needed, however, to measuring exposure to different types of noise (continuous, intermittent, impact/impulse) in different settings. Instruments are needed to evaluate the non-auditory effects of noise exposure (e.g., cardiac stress, high blood pressure). Current instruments are required to comply with national or international standards, but no entity certifies that the instruments comply.

Research Priorities

1. Reexamine the basis for current damage risk criteria. Mr. Kardous called for seeking universal consensus on a new set of criteria.
2. Determine the relationship between DRMs, metrics, and behavior modification to understand whether workers change their behavior in response to instant feedback from a monitor.
3. Develop new sensor technology (e.g., microphones, acoustic mannequins) that can be used in more settings, such as law enforcement.
4. Establish metrics to evaluate performance and measure the economic impact of implementing a solid hearing conservation program (e.g., savings on hearing compensation claims).
5. Develop a repository of exposure and risk data to help assess damage risk criteria and develop metrics, for example. Divisions throughout NIOSH have decades' worth of research data that could be linked together to create a rich database for analysis.

Mr. Brauch added that, like others, the field of noise exposure suffers from being a small market of limited potential profitability to manufacturers. However, advancements in the consumer electronics market benefit the field, and European markets are seeking technology that not only measures but also analyzes exposure. He also emphasized that preserving hearing has significant economic benefits; for example, it increases survivability among soldiers in the field. Employers need more education about the return on investment of addressing noise exposure.

Discussion

Participants pointed out the difficulty of assessing hearing loss with existing mechanisms, which measure the effect of exposure, not the exposure itself. Mr. Kardous stressed the need for frequent monitoring over time of the workplace to evaluate and address environmental concerns. Another participant emphasized the role of supervisors in educating workers about safe work practices, providing tools to mitigate individual risk, and using DRMs and other methods to address the work environment.

Radiation
Monitors: Jeri Anderson, PhD, NIOSH; Mark D. Hoover, PhD, NIOSH; Cynthia G. Jones, PhD, Nuclear Regulatory Commission
Rapporteur: Pam Drake, PhD, NIOSH

Dr. Hoover summarized the life-cycle approach to development of instrumentation and said that radiation detection efforts would benefit from a mechanism that combines all the relevant factors (e.g., temporal and historical issues) into an integrated display.

Research Priorities

1. Develop new technology for biological DRMs that are direct-reading, efficient, and available, using biodosimetry and bioassays, for example, which are already in use overseas.
2. Reduce size and increase speed of neutron radiation detection for all energies.
3. Establish mechanisms for independent third-party testing of instruments.
4. Develop methods and standards for detecting airborne particles (for chemical, biological, radiological, and nuclear threats) for immediate first responders.

Dr. Hoover added that standards for data collection, management, and transmission must be harmonized, including use of voice, video, and positioning data.

The breakout group identified five potential roles for NIOSH:

- Evaluate and report on real-life operator experience with instruments in various industries—both routine and emergency operations, international and domestic populations—and the possible transfer of emerging technology to the United States.
- Expand participation in the Inter-Agency Board to develop equipment standards and enhance interoperability for all chemical, biological, radiological, and nuclear threat detection approaches.

- Expand role in developing national and international standards.
- Identify gaps in safety practices nationwide. Develop training materials and guides to bridge gaps. Identify opportunities for solutions using DRMs.
- Collaborate with stakeholders on development and implementation of new DRMs.

Discussion

Dr. Jones described a 2002 oil refinery explosion that exposed workers to radiation. She explained that the U.S. testing facility was not up and running as anticipated, so her agency had to send samples overseas. She called on participants to anticipate potential needs and look to emergency responders for models of rapid response. Dr. Jones added that any training materials developed by NIOSH should include stakeholder input and incorporate public comments.

Surface Sampling & Biomonitoring
Monitors: John Snawder, NIOSH; Matthew Magnuson, PhD, EPA
Rapporteur: Debbie Sammons, NIOSH

Ms. Sammons said that NIOSH combined surface sampling and biomonitoring into one session because they can be complementary in some cases. The nature of the contamination may lead an investigator to examine an individual more closely for effects. Conversely, when biomonitoring reveals exposure but air samples do not provide information, surface sampling may identify the source of contamination. Ms. Sammons described recent advances in the field and said there is enthusiasm for the potential application of existing technologies to identify volatile organic compounds in exhaled breath.

Research Priorities

1. Develop standards to ensure that products live up to manufacturers' claims and to identify what a given product can or cannot do in various circumstances. One organization should oversee standards development.
2. Address accreditation to further ensure manufacturers adhere to standards and ensure that accreditation mechanisms are defensible in court.
3. Establish training for users on how DRMs work, what they can and cannot do, and how to interpret results.
4. Determine the purpose of DRMs (e.g., screening, mitigation) and what constitutes and acceptable DRM for that purpose. Action levels (i.e., exposure levels that require action be taken) are needed but should be developed after standards are established.
5. Identify new biomarkers and sensors, partnering with other organizations to leverage time and funds and seeking new uses for existing technology.

Discussion

Mr. Snawder clarified that new methodologies combined with cheap and abundant computing power make it possible to take exhaled breath samples from individuals and air samples at the same time to evaluate the presence and absorption of volatile organic compounds. It is now easier to gather much more data and to process those data to assess exposure. A participant suggested looking at other biomonitoring techniques as well.

Mr. Snawder cautioned against developing standards without providing sufficient training and guidance that address how to interpret data gathered by DRMs and how to address the findings. Workers are more likely to embrace DRMs when they receive education that empowers them to understand and address their own exposures. Participants called for more guidance specifically on what the results of surface sampling indicate, what should be done in response to those results, and what is appropriate for sampling. Some participants mentioned existing standards for surface sampling. Both ISO and the American Industrial Hygiene Association have accreditation standards for laboratories; both organizations also have mechanisms in place that could be used to develop standards for DRMs. Dr. Ashley said that NIOSH is seeking help from other organizations and experts to begin addressing action levels.

Closing

Dr. Coffey thanked all those involved and said the proceedings of the meeting would be posted for further review. He anticipated that the proceedings would include a feedback mechanism to garner more input on the research priorities. Dr. Coffey emphasized that the meeting represents the first step in a process that will inform the NIOSH agenda.

D.R.E.A.M. WORKSHOP

General Session

Direct-Reading Exposure Assessment Methods Workshop Agenda - General Session

November 13, 2008

8:00 – 12:15 P.M.	**General Session** *Christopher Coffey – Moderator* Chief, Laboratory Research Branch Division of Respiratory Disease Studies National Institute for Occupational Safety and Health
8:00 – 8:05 AM	**Welcome** *Christine Branche, PhD* Acting Director National Institute for Occupational Safety and Health
8:05 – 8:10 AM	**Introductory Remarks** *John Howard, MD* Consultant
8:10 – 8:15 AM	**Overview of Workshop** *David Weissman, MD* Director, Division of Respiratory Disease Studies National Institute for Occupational Safety and Health
8:15 – 9:00 AM	**Part I: Radiation detection in the 21st century- Basics, sources, applications and challenges** **Part II: Impact of the Department of Homeland Security on radiation detection** *Morgan Cox* Chairman, IEC TC 45
9:00 – 9:45 AM	**DRMs and what they mean to the worker** *Jon Volkwein* Research Physical Scientist Pittsburgh Research Laboratory National Institute for Occupational Safety and Health *Dennis O'Dell* Administrator for Occupational Health and Safety United Mine Workers of America

Direct-Reading Exposure Assessment Methods Workshop Agenda - General Session

9:45 – 10:30 AM	**Validation of Direct Reading Methods (and how NOT to validate them)** *Matthew Magnuson, PhD* Research Chemist Environmental Protection Agency
10:30 – 10:45 AM	**~ Break ~**
10:45 – 11:05 AM	**Integration of activity through position** *Peng-Yau (Eric) Wang, PhD* Associate Professor National Central University, Taiwan
11:05 – 11:30 AM	**Experiences with Direct Reading Instruments for Exposure Assessments** *William Heitbrink, PhD* Associate Professor University of Iowa
11:30 – 12:15 PM	**Issues Motivating the Collection of Occupational Exposure Data** *Stephen Rappaport, PhD* Adj. Professor of Environmental Health University of California, Berkeley

Overview of Workshop

D.R.E.A.M.
WORKSHOP

David Weissman M.D.
Manager,
Exposure Assessment Cross-Sector Program
DQW4@cdc.gov
304-285-6261

CDC

WORKPLACE SAFETY AND HEALTH

NIOSH

Overview of Workshop

2

- **Purpose**: to gather diverse stakeholder input on research needs in the area of direct reading methods for assessing occupational exposures.
- **Day 1**
  - General Session: state-of-the-art presentations addressing issues in direct reading exposure assessment methods that are relevant to a broad range of employment sectors and occupational hazards, including regulatory framework, validation, and approach to collecting and using data.
  - Concurrent Breakout Sessions: organized by hazard, including: gases / vapors; aerosols; ergonomics / vibration; noise; radiation; and surface sampling / biomonitoring.
- **Day 2**
  - Summary Session: Reports from each breakout session on the specific research needs for each type of occupational hazard.

CDC

NIOSH

Part one
Radiation detection in the 21st century
Basics, sources, applications, hazards & challenges

Morgan Cox, CHP
morgancx@swcp.com
October 2008

Radiation detection in the 21st century

- Memorial

- F Herb Attix - Dosimetry
- John Cameron- Medical physics
- Perry Davison- Nuclear engineering
- Mario Overhoff- Tritium detection
- Elmer Stewart- Scintillation technology
- Carl Swinehart- LiF & TLD materials
- G Hoyt Whipple- Health physics

Radiation detection in the 21st century

- Status, sources, applications, and hazards by radiation type
- Alpha
- Beta
- Photons (gamma rays & x-rays)
- Neutrons

Radiation detection in the 21st century

- Alpha radiation detection

α particles are Helium atoms stripped of electrons and hence positively charged (++).

α particles are emitted at single discrete energies.

An example is ^{222}Radon at ~5.5 MeV (exactly 5.495).

α Range in air= 0.56E in cm/MeV (<4 MeV).

= 1.24 – 2.62E (<4E<8 MeV).

α emitters of concern include isotopes of U & all of the transuranic radionuclides, esp ^{238}Pu & ^{239}Pu.

Naturally occurring α emitters include U and Th.

Man-made α emitters include Pu and Np.

Radiation detection in the 21st century

- Alpha radiation detection
- External to the human body alpha particles are measured using GM, ion chamber, proportional counters and solid state detectors close to the alpha source as surface contamination.
- Taken internally alpha particles can only be measured via bioassay of body fluids, waste, and tissue samples.
- So alpha radiation is primarily an internal dosimetric concern from inhalation, ingestion and wounds.

Radiation detection in the 21st century

- Alpha radiation sources
- Primarily early in the nuclear fuel cycle; in U mining, U milling and fuel production as aerosol hazards;
- In nuclear weapons programs in glove boxes and fume hoods also as aerosol hazards from releases;
- Electroplated alpha calibration sources pose as hazards only if mishandled.

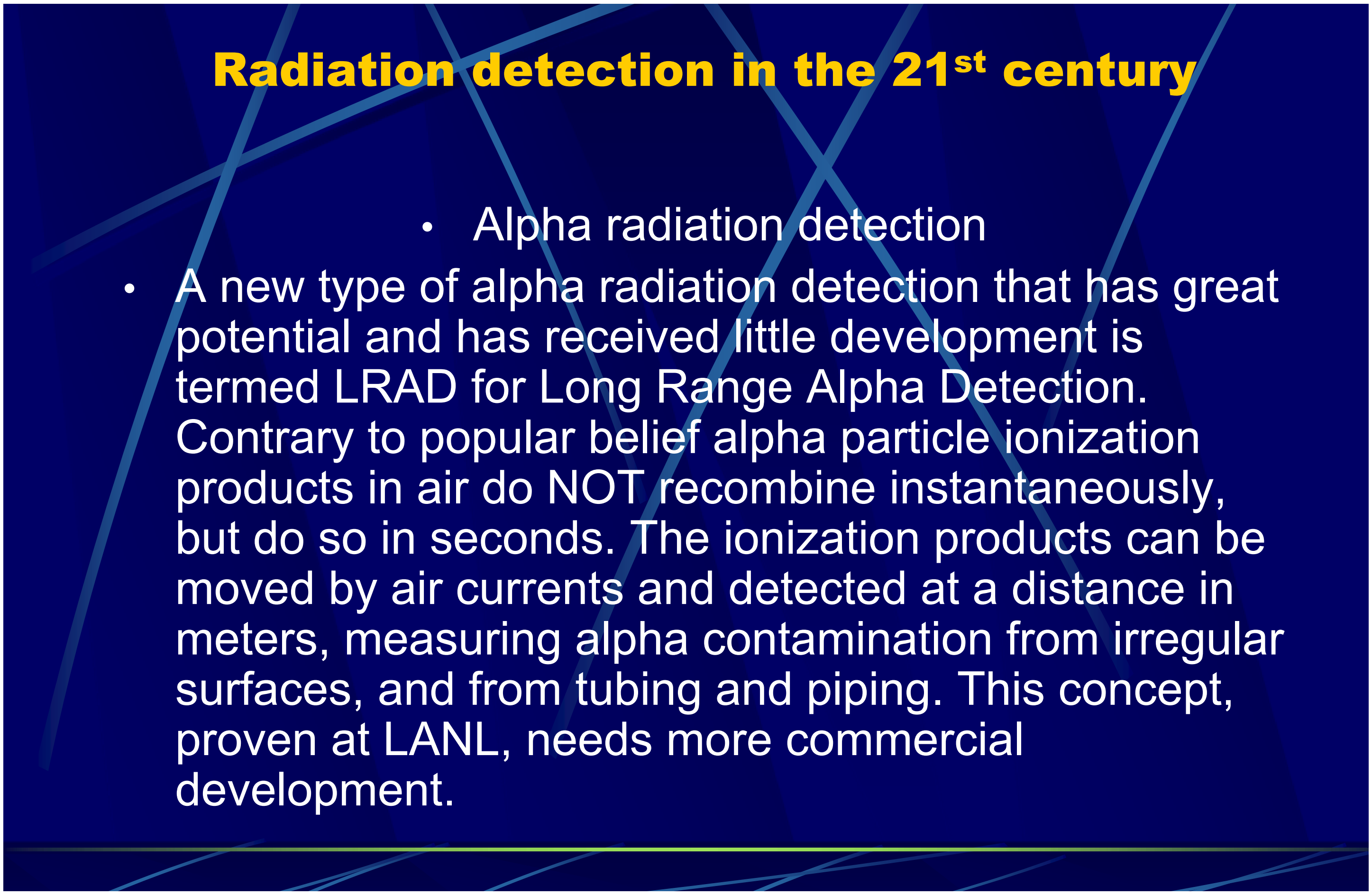
Radiation detection in the 21st century

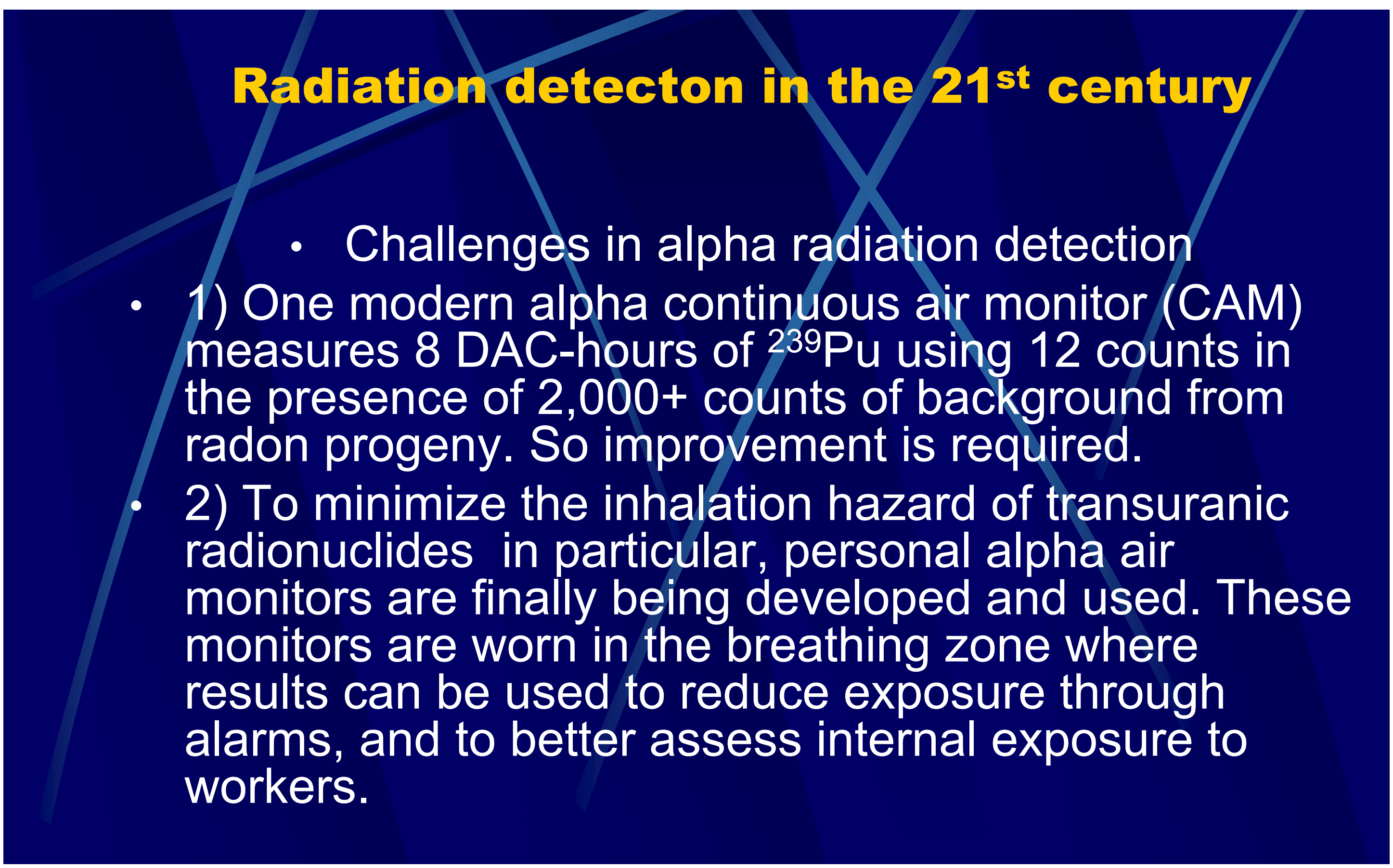
- Alpha radiation detection

- Alpha radiation detection for aerosol measurements is now at a sophisticated level based on alpha spectroscopy (energy) capable of separating radon and thoron backgrounds from releases of Pu or U in the workplace, in effluents and in the environment.
- Fortunately background radon and thoron alpha particles have energies >6MeV, whereas Am, Pu and U alpha particles have energies <6MeV.

Radiation detection in the 21st century

- Alpha radiation detection
- Alpha particle detection seems to have reached a
- technological plateau, needing some algorithmic improvements in converting spectroscopic data for collected aerosols into derived air concentration (DAC) and DAC-hour or dosimetric data. Peak-fitting and region of interest techniques are improvements.
- Alpha surface contamination measurements are now routine by using portable survey instruments, portal monitors and/or by evaluating alpha smears or other samples.


Radiation detection in the 21st century
• Alpha radiation detection
• A new type of alpha radiation detection that has great potential and has received little development is termed LRAD for Long Range Alpha Detection. Contrary to popular belief alpha particle ionization products in air do NOT recombine instantaneously, but do so in seconds. The ionization products can be moved by air currents and detected at a distance in meters, measuring alpha contamination from irregular surfaces, and from tubing and piping. This concept, proven at LANL, needs more commercial development.


Radiation detecton in the 21st century
• Challenges in alpha radiation detection
• 1) One modern alpha continuous air monitor (CAM) measures 8 DAC-hours of ^{239}Pu using 12 counts in the presence of 2,000+ counts of background from radon progeny. So improvement is required.
• 2) To minimize the inhalation hazard of transuranic radionuclides in particular, personal alpha air monitors are finally being developed and used. These monitors are worn in the breathing zone where results can be used to reduce exposure through alarms, and to better assess internal exposure to workers.

Radiation detection in the 21st century

- Beta radiation detection

- β particles are negatively charged electrons emitted in a continuum of energies, specific to that radionuclide. β energies are expressed as E_{max} and E_{ave} where the average is ~1/3 the maximum.
- β particle range using Feather's rule (E > 0.6 MeV) R = 0.542 E – 0.133, where R is range in mg/cm^2.
  β particle range in air is ~3.5 meters/MeV.
  β particle emitters include ^{60}Co, ^{90}Sr/^{90}Y, plus most fission products and activation products. ^{90}S/^{90}Y are uniquely pure β emitters. ^{40}K is a naturally occurring radionuclide.

Radiation detection in the 21st century

- Beta radiation detection

- β particles are primarily hazardous as nonpenetrating radiation for skin exposures.
- β radiation detectors include GM, ionization chambers, proportional counters, and to lesser extent solid state and scintillation counters.
- β radiation can also be an internal hazard through inhalation, ingestion and wounds.
- β radiation is normally accompanied by γ radiation.

Radiation detection in the 21st century

- Beta radiation detection

- Airborne β radiation is a serious hazard in Uranium mining, milling and nuclear fuel processing. Airborne β radiation is a concern as a hazard at nuclear power plants, in the radiopharmaceutical industry, in medical laboratories, and elsewhere in industry.
- β radiation is normally measured as gross beta and beta spectroscopy is rarely used or needed. However, newer microprocessor-based technology coupled with advanced scintillation configurations make beta spectroscopy more available.

Radiation detection in the 21st century

- Beta radiation sources

- Many current thickness gauges use beta emitters such as $^{90}Sr/^{90}Y$ to measure the thickness of metal coatings where beta backscatter is operative.
- Beta emitters are also used in density gauges, for example, with snow gauges.
- Beta radiation sources can be readily shielded using materials of low atomic number such as plastics ($\sim CH_2$) and aluminum.
- Beta sources also produce brehmsstrahlung or braking radiation in materials giving rise to x-rays.

Radiation detection in the 21st century

- Challenges in beta radiation detection

- Measuring the precise dose rate or dose from beta emitters is complicated by the fact that the beta energies are varying over the continuum, and in many operational cases a number of beta emitting radionuclides are together as with mixed fission or mixed activation products.
- Low energy beta particles from tritium, ~19 keV E_{max} and ~7 keV_{ave}, are extremely difficult to measure because of their short range. Overhoff, et al.

Radiation detection in the 21st century

- Photon radiation detection

- Photons consist of gamma rays and X-rays & are both considered penetrating radiation.
- Gamma rays are emitted from the nucleus whereas x-rays result from orbital electron transitions.
- Gamma ray sources include ^{60}Co and ^{137}Cs with energies at 1.25 MeV (average) and 0.662 MeV respectively. Nearly all gamma ray emitters also emit β particles. ^{40}K is a naturally occurring β/γ emitter, with a gamma ray energy of 1.46 MeV, and a half-life of 1.26 X 10^9 years.

Radiation detection in the 21st century

- Photon radiation detection
- Photons interact with matter via three processes:
- Photoelectric absorption at lower energies;
- Compton effects, attenuation & scattering at intermediate energies, and
- Pair production for energies >1.2 MeV.

Radiation detection in the 21st century

- Photon radiation sources
- Photon radiation sources deliver kilo-Rad and mega-Rad doses in sterilization for foodstuffs and other consumables.
- ^{137}Cs sources are considered as standard sources for radiation detection instrument calibrations, performance requirements and tests.
- ^{60}Co sources, once considered a standard source in radiation therapy, have been largely replaced by high energy electrons from accelerators.

Radiation detection in the 21st century

- Photon radiation detection challenges

- Photon radiation detection is nearing the “state of the art” in detection using primarily ionization chambers

  for exposure rate and exposure measurements, and scintillation detectors and Germanium detectors for energy spectroscopic measurements. New photon methodology is emerging with new detector types.

  Photon dosimetry is well covered by TLD & OSLD.

  The penetrating nature of photons makes them relatively easy to measure and to identify the photon emitters. More on this issue in Part two.

Radiation detection in the 21st century

- Neutron radiation detection

- Neutrons are uncharged nuclear particles slightly larger in mass than protons.
- Neutrons range most widely in energies from 10^{-3} eV to $>10^{2}$ MeV or by $>10^{11}$! Hence the method of detecting neutrons varies from capture at lower and intermediate energies, to moderation of higher energies to lower energies followed by capture, to threshold effects at high energies.
- Neutrons are considered the “mavericks” in radiation detection with no charge and the wide energy range.

Radiation detection in the 21st century

- Neutron sources

- Neutron sources include fission reactors, power and experimental, accelerators, radionuclide sources such as $^{238/239}$PuBe, ^{241}AmBe and spontaneous fission emitters, and hence neutron emitters, such as ^{252}Cf. The isotopes of Plutonium and Uranium, also termed “special nuclear materials”, are also spontaneous fission emitters of neutrons. The importance of this characteristic will be covered in more detail in Part two.
- Neutron shields are low Z materials such as water & paraffin (CH_2).

Radiation detection in the 21st century

- Neutron radiation detection

- Being nonionizing, neutrons are detected indirectly.
- Neutrons are mainly detected through interactions such as the n-α reaction in ^{6}Li and ^{10}B compounds.
- Neutron detectors include ^{3}He, BF_3 (^{10} B, n-α), ^{6}LiI gas tube detectors, ^{6}LiF and $Li_2B_4O_7$ TLD materials, and some plastic scintillators, ~CH_2 in composition, through proton recoils.
- So neutrons are detected via the resultant α particles and protons ($^{1}H^{+}$) produced through interaction.

Radiation detection in the 21st century

- Neutron radiation detection
- The major challenges in modern radiation detection are those related to neutron detection. For example, the IAEA has appealed for smaller, faster and smarter neutron detectors for years, mainly for the detection of special nuclear materials in illicit trafficking across international borders. Some of this issue will be discussed in more detail in Part two.
- Two possible successful approaches to this challenge are illustrated in the next slides.

Radiation detection in the 21st century

- Neutron detection challenges
- Possible solutions to neutron detection with smaller and smarter detectors/instruments:
- The Stanley Kronenberg carbon fibre detector with two coupled ion chambers, one with teflon walls (no H) and one with CH_2 walls. The first measures ionic charge from photons, while the latter measures ions from photons and from recoil protons. The signal from one is internally subtracted from two resulting in real neutron detection. This is a development of the US Army needing only commercial investment. No one has picked up on this idea to date.

Radiation detection in the 21st century

- Neutron detection challenges
- A second possible smarter/smaller neutron detector:
- The Overhoff approach of using a small (100-300 cm^3) plastic (~CH_2) scintillator coupled to a small (0.5") photomultiplier tube. This technique has been demonstrated to be capable of measuring fast neutrons at low levels. The resultant photon pulses are much smaller than the neutron pulses and can be discriminated out of the picture. Mario Overhoff passed away in late 2005 and so this work needs to continue. This should be relatively easy for a commercial development. To date no one has picked up this effort.

Radiation detection in the 21st century

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- Evans, R, The Atomic Nucleus
- Kaplan, I, Nuclear Physics
- Mercer, T, Aerosol Technology in Hazard Evaluation
- Radiological Health Handbook (all editions)
- Rogers, D, Handbook of Nuclear Safeguards Measurement Methods

D.R.E.A.M.
WORKSHOP

Part two
Impact of the Department of Homeland Security (DHS) on radiation detection instrumentation

MORGAN COX, CHP

October 2008

Impact of the DHS on Radiation Detection Instrumentation

In memoriam

- John Leonowich, UNLV
- Sergio Lopez, MGPI
- George Newton, LRRI

May they rest in peace.

The DHS & Radiation detection

- Events/Milestones that precipitated the need for ionizing radiation detection, more and/or better:
- In the 19th century: The discovery of x-rays and natural radioactivity;
- In the 20th century: The medical uses of radiation, the advent of nuclear weapons and the emergence of nuclear power; and
- In the 21st century, the events of 9/11 & the formation of the Department of Homeland Security.

The DHS & Radiation detection

- Most of the earlier advances in radiation detection were for the purposes of radiation protection for workers, the public and/or the environment.
- For example, we can see the progress made in reducing exposures to workers by the uses of improved detection and dosimetry: first using film, then quartz fiber dosimeters, and now TLD, OSLD and electronic dosimeters. These latest forms of detection have lead to lowering doses to all concerned.

The DHS & Radiation detection

Similar analogies apply to the various types of radiation detectors with improvements to:

- -Ionization chambers;
- -G-M counters;
- -Proportional counters;
- -Scintillation detectors;
- -Solid state detectors; and some hybrid, combined and advanced detectors.
- Some examples.

The DHS & Radiation detection

Improved radiation detection technology & methodology are driven by three important forces, not necessarily in this order:

1) The needs & applications of various users;

2) The available current technology, and

3) Applicable regulations, federal, state and/or local.

The DHS & radiation detection markets

- By 2000 the overall market for radiation detectors was either stable or growing very slowly. Why?
- No new nuclear power plants were brought on line in the USA in ~25 years;
- US Department of Energy had nearly all of the instruments needed with few replacements; and
- Foreign competition was mainly fulfilling foreign requirements and competing for US markets.

Impact of the DHS

- The terrible events of 9/11 had little immediate effect on radiation detection.
- In late 2002 the DHS was proposed as a federal department.
- A threat from an RDD or “Dirty Bomb” was identified
- In November 2002 radiation detection experts were summoned to NIST to discuss new ANSI N42 standards needed quickly to cover instruments for uses by DHS-related personnel and agencies.
- The DHS officially became a federal department in January 2003.

Radiation detection markets

- By 2002 the overall market for radiation detectors was saturated or growing slowly. Why? Because there was little incentive to invest in new technology, and there were few new applications.
- Nuclear instrument manufacturers were merging and combining in an effort to maintain or increase market share. The number of manufacturers had decreased markedly. For example, affiliates in the Health Physics Society decreased in number from 114 in 1982 to 64 in 2008.

Direct effects of the DHS

- The DHS mandated the swift development of four new ANSI N42 instrument standards.
- The initial emphasis was on radiation *detection* and not on radiation *protection*, dose or exposure evaluation or reduction! Finding the device or the radioactive material was paramount.
- Then currently available radiation detectors were considered for possible use by DHS agencies.

The importance of quickly developing standards for test and evaluation of instruments was expressed most emphatically

- Battalion Chief Robert Ingram of the NYFD Center for Terrorism and Disaster Preparedness said:

  "We need these standards, and we need them yesterday!"

The first ANSI standards for the DHS

- ANSI N42.32 for personnel radiation detectors;
- ANSI N42.33 for portable radiation detectors;
- ANSI N42.34 for portable radionuclide identifiers; and
- ANSI N42.35 for portal radiation monitors.
- All four were initiated in late 2002; three were published in 2003, and the fourth in early 2004.
- Never before or since were ANSI standards developed so quickly!

DHS testing & evaluation (T&E) protocols

- The DHS also mandated the developments of rigorous Testing &Evaluation protocols to accompany and parallel the four ANSI standards.
- Some 200 models of the various and relevant instruments covered by the standards were evaluated by DOE laboratories:
- Lawrence Livermore National Lab,
- Los Alamos National Lab;
- Oak Ridge National Lab, and
- Pacific Northwest National Lab.
- The DHS testing in 2 phases was completed in 2005.

Demands for new technology

- What the DHS did with the mandates for new ANSI instrument standards and for more rigorous testing and evaluation protocols was to light a fire under the radiation detection industry! How?

- By demanding new ideas, new technology and some resultant new and better instruments. The DHS tied some funding requirements to the standards for the procurement of radiation detectors for homeland security users. This provides some incentives to develop and produce new, smarter, faster and smaller radiation detectors.

Examples of required new technology

- Some examples of needed new technology:
- ANSI N42.32 for personnel detectors has an option for neutron detection. This points to the need for a pocket-sized detector with both photon and neutron detector (s). None exists yet that fully meet the requirements of the standard!
- ANSI N42.33 for portable survey instruments has a requirement for stable performance from a few μR/h or background to 10 mR/h.

REQUIRED NEW TECHNOLOGY (CONTINUED)

- ANSI N42.34 for portable radionuclide identifiers also calls for neutron detection. Here we see the need for two different detectors in the same instrument, plus photon spectroscopy.
- ANSI N42.35 for portal monitors now includes personnel, vehicular and package monitors with photon spectroscopic and neutron detection capabilities.
- So some new technology has definitely been required to meet the needs of the DHS, but there is still room for improvement.

Examples of Commercially Available Instruments
(No Endorsement Implied)

Summary

- DHS emphasis has been on *detection* not protection, and innovative, new instruments are needed for detection.
- DHS has promoted miniaturization.
- DHS stimulated advanced photon spectroscopy.
- DHS has also stimulated better neutron detection.
- DHS has demanded better training, software, communications and more user friendly instruments.

The ANSI standards from ANSI N42.32 to ANSI N42.49 with a few exceptions are or will be published for use by DHS agencies. By general content these are:

- ANSI N42.32- personnel detectors
- ANSI N42.33- portable survey instruments (for photons)
- ANSI N42.34- portable radionuclide identifiers
- ANSI N42.35- portal radiation monitors
- ANSI N42.37- training with radiation detectors
- ANSI N42.38- spectroscopy-based portal monitors
- ANSI N42.39- portable neutron detectors
- ANSI N42.41- active interrogation systems (for cargo)

More ANSI standards for DHS

- ANSI N42.42- data formatting for radiation detectors
- ANSI N42.43- mobile & transportable portal monitors
- ANSI N42.44- checkpoint cabinet x-ray systems
- ANSI N42.46- photon and x-ray systems for cargo and vehicles
- ANSI N42.48- spectroscopic personnel detectors
- ANSI N42.49A and B- personal emergency radiation detectors, PERDs, alarming and non-alarming

ANSI standards for the DHS

Leadership

Bert Coursey- DHS/NIST

Lisa Karam- NIST

Mike Unterweger- NIST

Joe McDonald- PNNL (emeritus)

Lou Costrell- NIST (emeritus)

Sources for ANSI N42 standards

- morgancx@swcp.com
- unterweg@nist.gov
- louiscostrell@nist.gov
- http://www.hssd.us/ ANSI Homeland Security Database
- https://www.rkb.us/ Emergency Responder website
- New volunteers for standards work in the audience?


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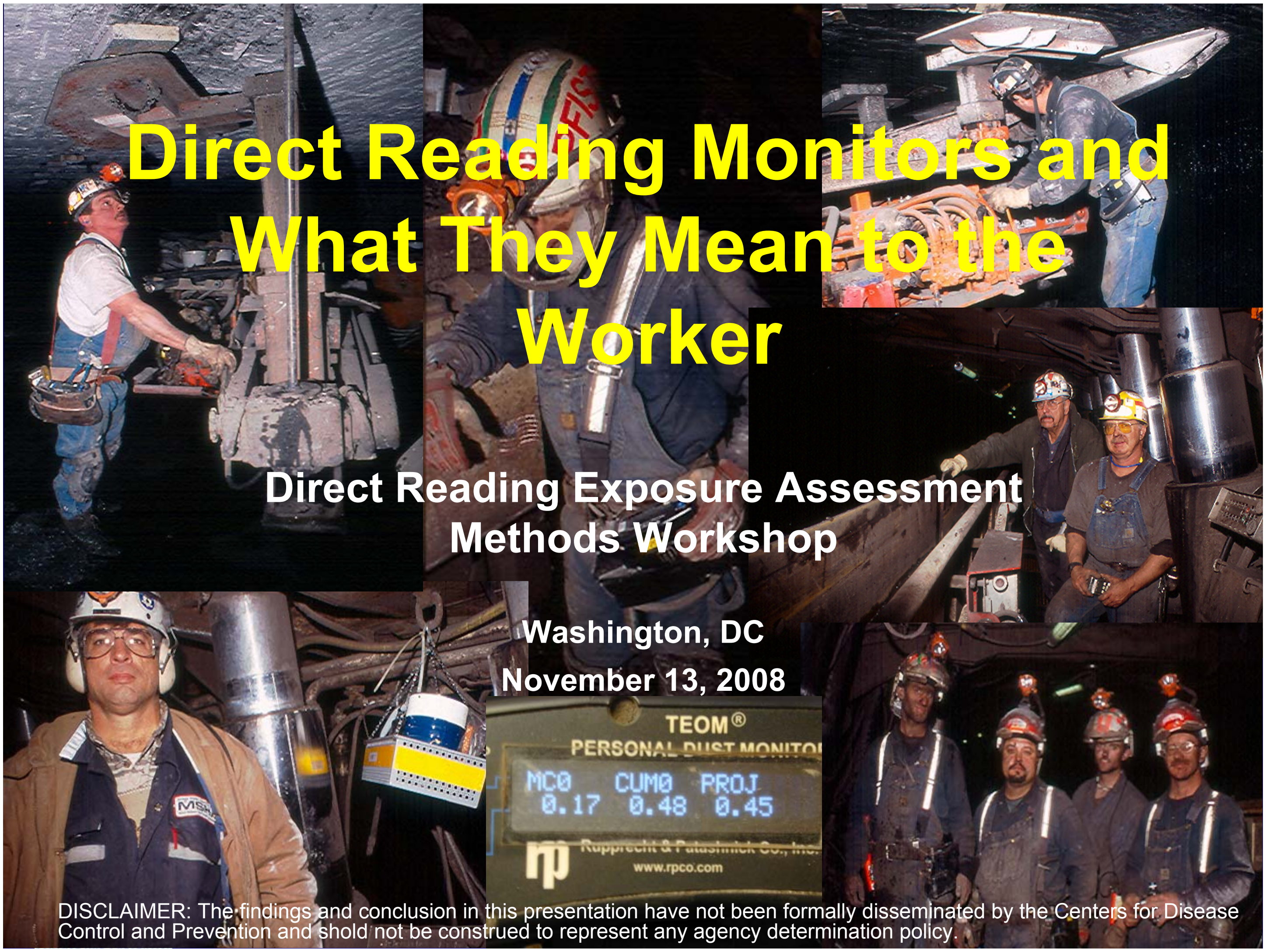


Overview

- Workshop is to think about how the emerging DRM technologies might improve worker health
- Present topics for discussion and thought in breakout sessions from the perspective of impact on the worker

Distinguish different needs direct reading monitors

Immediate

- Short term threats to life
  - Explosive gases
  - Toxic materials.
  - Suffocation hazards
- Need obvious for current threat
- Mature stage of development

Indirect

- Long term threats to health
  - Cancer
  - Silicosis
  - Coal workers pneumoconiosis
  - Noise
- Need seems less obvious

Why are direct or short term measurements relevant to long term health issues?

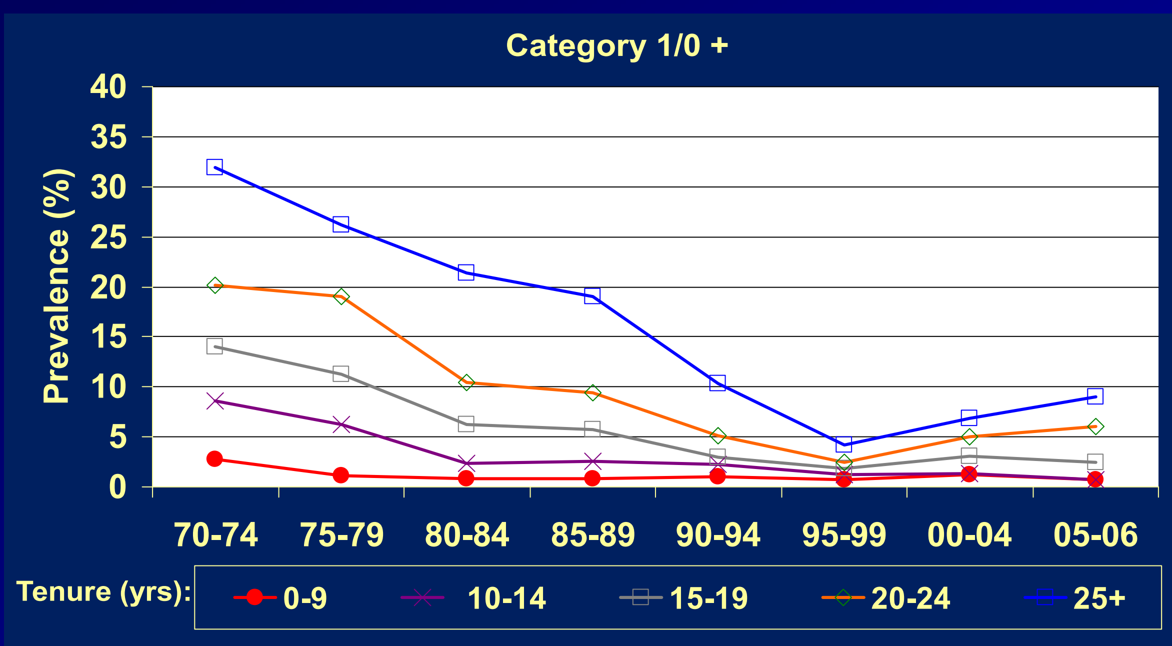
- Historically periodic hazard assessment of work place is generally adequate.
  - Measure levels
  - Identify sources
  - Develop engineering controls for sources
  - Periodic monitor levels.
- Periodic assessment approach becomes less effective when
  - Workplaces continually move
    - Mining
    - Construction
    - Agriculture
  - Contaminant changes spatially or temporally

Mining as an example -- Current practice in mining is periodic

- Mines submit a ventilation control plan that lists what engineering controls are to be in place
- Mines measure dust levels every 2 months for 5 consecutive shifts.
- Inspectors monitor compliance with engineering aspects of the plan on a more frequent basis

Results of this strategy

Trends in coal workers' pneumoconiosis prevalence by tenure among examinees employed at underground coal mines, U.S. National Coal Workers' X-Ray Surveillance Program, 1970-2006



In response -

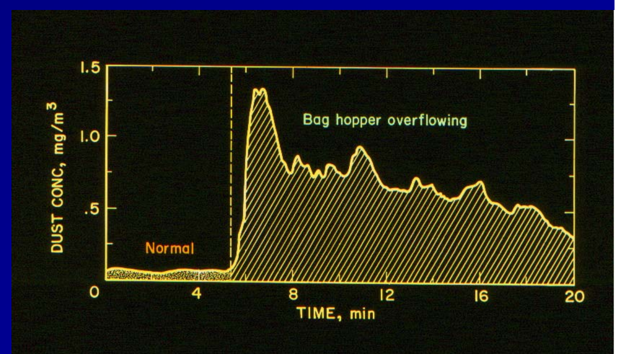
- Sec. Labor commissioned panel in 1996
  - Labor
  - Industry
  - Government
  - Academia
- Panel made recommendations
- Recommendations relevant to DRM's
  - Continuous and accurate monitors should be used
  - More frequent sampling
  - Structured training related to dust control issues
  - Increase miners participation in dust sampling program
  - Explore innovative ways to enhance compliance
  - Improve confidence in mine dust sampling program

DRM Issues for discussion

1. Continuous monitoring
2. Frequency of sampling
3. Worker participation and training
4. Verify exposures
5. Innovative approaches

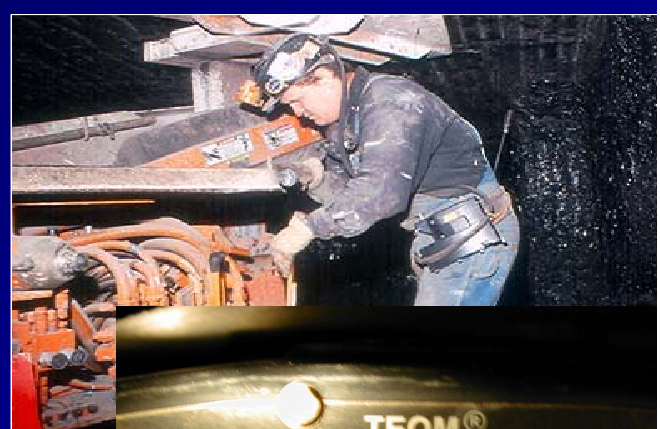
1. Continuous Monitoring

- IH professionals already use available DRMs
  - Identify sources
  - Decide where to sample
  - Where to direct resources
- Requires skill to use and interpret
- Are available DRMs easy to use?
  - Accurate
  - Unambiguous results



Worker need -- continuous monitoring

- Prime objective – make sampling invisible to user
  - Do not get in the way
  - Keep light weight and streamline
  - Integrate into work environment
- Provide simple interface
  - To use
  - To understand
- Accuracy may depend on use
  - Less accurate for warnings
  - Greater accuracy for compliance
- Intuitive – No “interpretation” of the meaning of the data



2. Frequency of sampling

Depends on hazard

- Lower frequency sampling
  - Low historical levels
  - Low toxicity
  - Adequate engineering controls
- Higher frequency sampling
  - High toxic hazard
  - Exposures are at the limits of engineering controls
  - High variability of hazard – mobile work places
  - Compliance history
- Cost

Workers perspective -- frequency of sampling

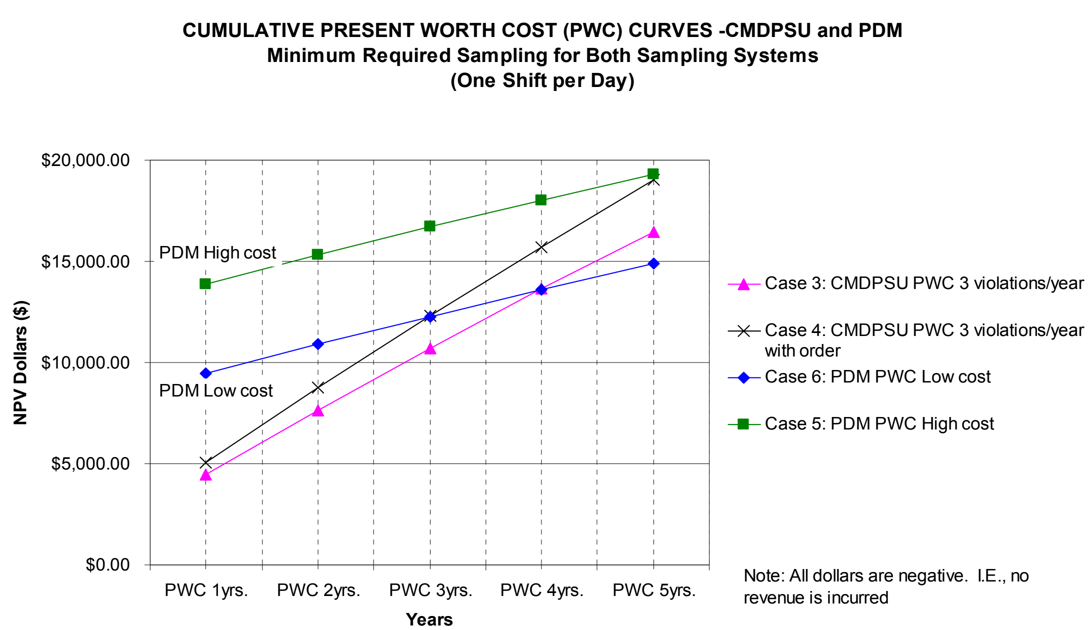
- Priorities
  - No interference with work
  - Protect my job
  - Protect health
- Do not over do it –
- Enable worker and management to manage risk

DRM Cost Analysis

- Conduct a ROSHI analysis
- DRM versus reference methods
  - Purchase price
  - Operating cost
    - Labor
    - Material
  - Citation cost avoidance - time
  - Sampling schemes
    - Continuous
    - Intermittent
  - Operating life

Example of PDM Cost Analysis –

Engineering analysis from company perspective



Economic Analysis

- Future economic evaluation of DRM's should examine societal costs and benefits
  - Cost of illness to federal & state govt. – workers comp
  - Medical costs of associated illness (COPD)
  - Insurance costs

3. Worker participation and training

- Modern workforce is better educated
- Level of participation will vary
  - Very involved
  - Could care less
- Functionality
  - Objective is not another decimal point in accuracy, but to prevent worker overexposure
  - How accurate is accurate enough
    - Understand the other errors
    - Appropriate trade off analysis to decide
- DRM as a tool to educate

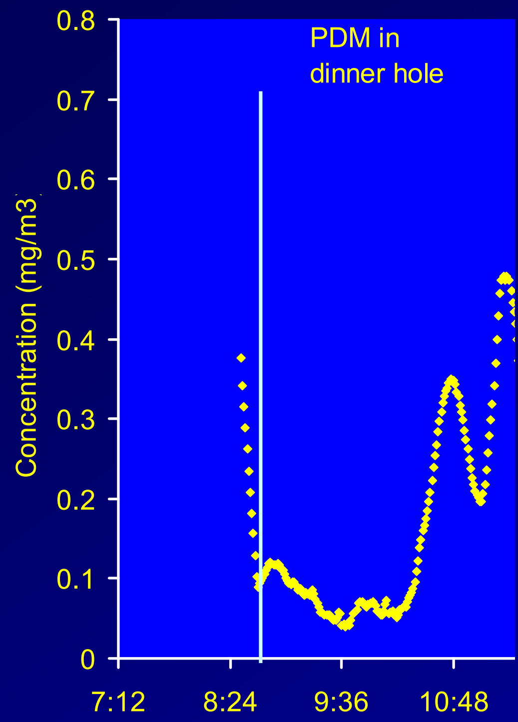
Participation through Partnership

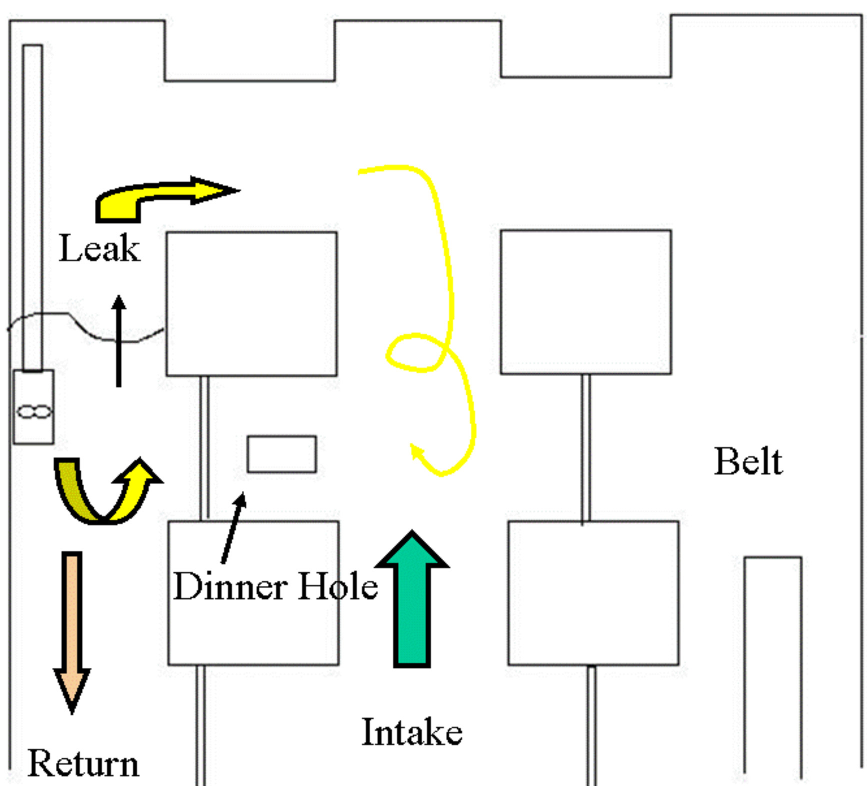
- Multiple participants strengthen development
- Workers involvement
  - Assess need
  - Development of solution
  - Consultation in design
  - Participation in testing
    - Protocol development
    - Testing
    - Feedback

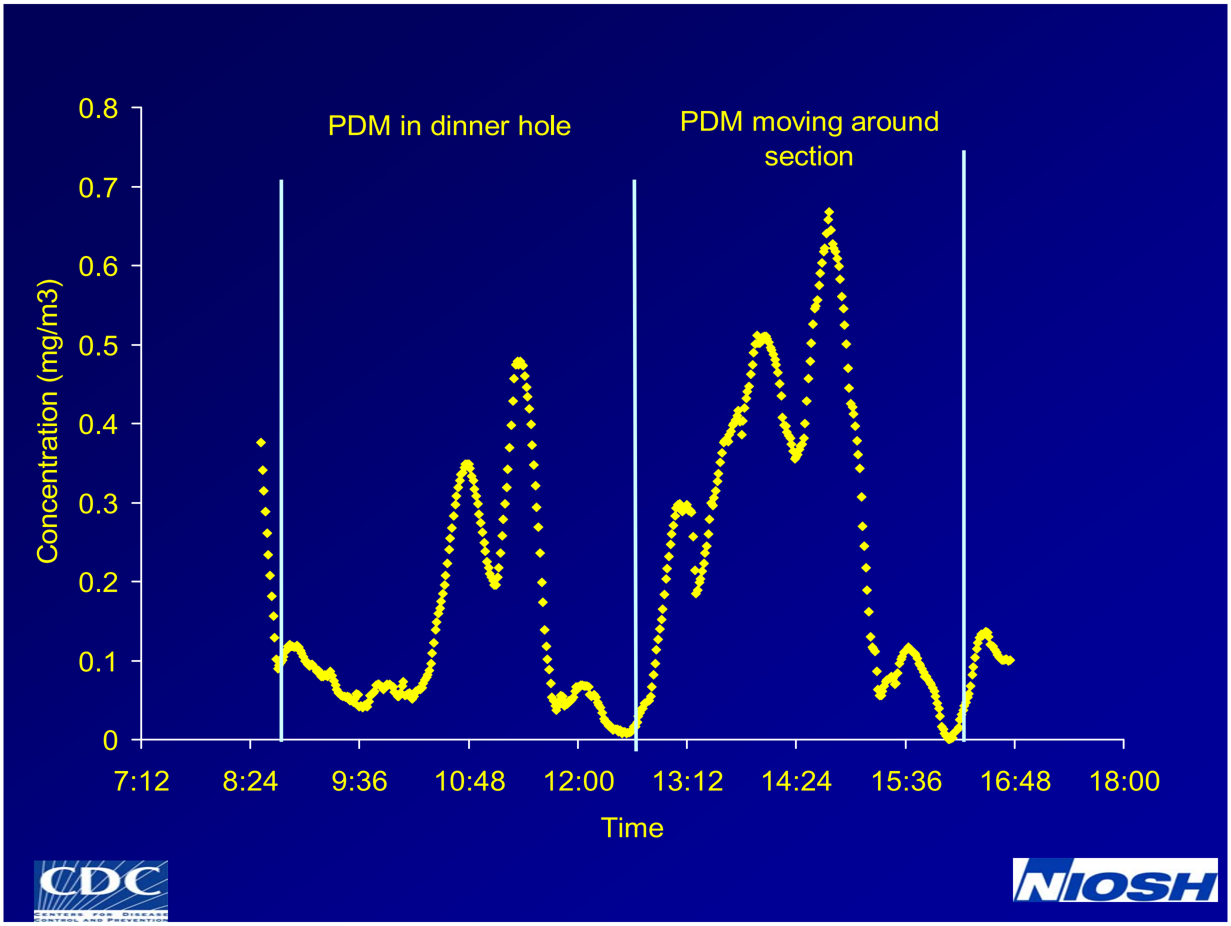
Example of timely information

"Discovery of a Leaking Curtain"

- Benefit of immediate feedback
  - Education
  - Action – result
  - Understanding the connection between cause and effect.
  - Avoid over exposure
- PDM worn by a miner while on break in the dinner hole
- Observed an increase in the dust levels in the intake.
- Located source


PDM in
dinner hole
Concentration (mg/m3)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
7:12
8:24
9:36
10:48


Leak
Belt
Dinner Hole
Intake
Return



4. Verify exposure

- Periodic sampling – time delay
  - Allows time for conditions to change
  - Recollection of events that resulted in the exposure are forgotten
- DRM's provide timely, on-the-spot, data
  - Worker, manager, and inspector see same information at same time
  - Unambiguous arbitrator of need

5. Novel

- Psychological
  - Noise example
  - PDM example
- Empowerment
  - Employee
  - Management

Novel – Psychology Model

- Israel noise study
  - Controlled group study
  - One group saw real-time noise exposure data
  - One group did not
  - Group with information lowered exposure
- NIOSH PDM (Peters, et al. J. Int. Soc. Resp Prot. 4:2007. & NIOSH IC 9501, 2008)
  - Miners with knowledge of exposure data reduced exposure

Model of How Miners' Use Personal Dust Monitor Feedback

1. Diagnosis
2. Action Planning & Intervention
3. Evaluation
4. Institutionalization

Feedback

Behavior Change

CDC CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH

Interview findings generally support the model

- Most miners paid attention to PDM feedback
- Most miners tried to reduce exposure
- One crew reduced their average dust exposure 60% in 4 weeks

CDC CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH

DRM's Empower

- Worker
  - Combine job experience with timely data
  - Understand connection
  - Act to improve situation
    - Individually
    - Through management
- Management
  - Timely data allow risk to be managed
  - Demonstrate their duty to provide a healthy workplace

Challenges -- How can we improve workers health with DRM's?

Issues for discussion

1. Continuous monitoring
2. Frequency of sampling
3. Worker participation and training
4. Verify exposures
5. Innovative approaches


D.R.E.A.M.
WORKSHOP

BCOA-UMWA Consensus Principles (selected)

Respirable Dust Monitoring with (or without) the PDM

BCOA-UMWA Consensus

- MSHA should do all compliance sampling.
- The PDM would be the sole means of monitoring exposure for compliance.
- Sampling information would be available to all interested parties

Consensus, cont'd

- Exploit PDM's two capabilities:
  - Improve dust control by identifying sources of excess exposure and
  - A means of determining non-compliance

Consensus, cont'd

- Samples should be taken
  - for a for full shift and
  - for work weeks longer than 40 hours, the EL would be adjusted by applying Haber's rule: C*x*T=K, equivalent to 2.0 mg/m^3 for 40 hours per week
- There would be no consideration of measurement error in determining non-compliance.

Miners' Concerns

- Data would be used in compensation hearings for black lung
- Somebody will find a way to cheat
- Data would be used against miners on the job if exposure was "too high":
  - Reassignment
  - Denial of overtime


D.R.E.A.M.
WORKSHOP

EPA
United States
Environmental Protection
Agency

Validation of Direct Reading Methods
(and how NOT to validate them)

Matthew L. Magnuson

Office of Research and Development
National Homeland Security Research Center

November 13, 2008

EPA
United States
Environmental Protection
Agency

Outline

1. Intro to EPA's National Homeland Security Research Center

2. Validation topics
   - Validation goals
   - Performance Criteria
   - Validation of entire process, not just instrumental component
   - Importance of Third Party Testing
   - EPA Technology Testing and Evaluation Program

3. Validation related needs
   - Technical
   - Policy
   - Training

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1. Introduction to EPA's National Homeland Security Research Center

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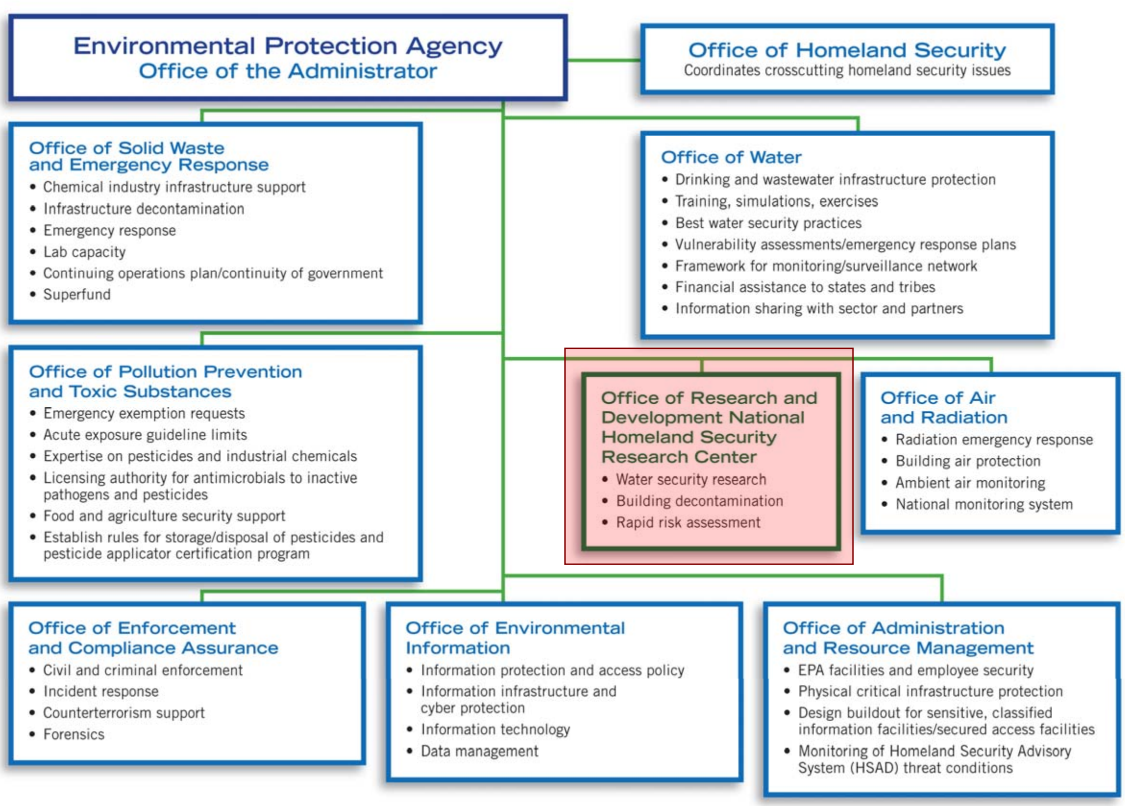
Homeland Security Roles at EPA



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Authorities

The Public Health Security and Bioterrorism Preparedness and Response Act of 2002, together with Homeland Security Presidential Directives (HSPDs), charges EPA with protecting our nation's critical water infrastructure and decontaminating indoor and outdoor areas following an incident.

HSPD 7 – Defines EPA as Sector Specific Agency for drinking water and water treatment systems

HSPD 9 – Requires EPA to develop a comprehensive, and fully coordinated water quality surveillance/monitoring system and an interconnected laboratory network

HSPD 10 – Requires EPA to address risks from biological agents and develop strategies, guidelines, and plans to decontaminate persons, equipment, and facilities (classified)

4

EPA Roles in Homeland Security

- Protecting water and water infrastructure
- Indoor and outdoor clean-up following attack or natural disaster
- Reducing vulnerability of the chemical & hazardous materials sector
- Research to protect water infrastructure & buildings
- Hazardous materials emergency response

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United States Environmental Protection Agency

NHSRC Primary Areas of Focus (founded 2002)

- **Water Infrastructure Protection Division** is charged with conducting research to prevent, detect, and respond to terrorist attacks on the nation's drinking water and wastewater systems.
- **Decontamination and Consequence Management Division** focuses on decontamination of buildings and outdoor environments, as well as the safe disposal of contaminated materials
- **Threat and Consequence Assessment Division** investigates human exposure to chemical, biological, and radiological contaminants to define dangerous levels of these contaminants and establish protective cleanup goals
- **Response Capability Enhancement Group** works directly with emergency responders and local governments to provide tools and information needed to make informed decisions in the event of an attack
- **Technology Testing and Evaluation Program** evaluates technologies that show potential for use in homeland security applications. These evaluations are used by water utility operators, building owners, emergency responders, and others to make informed decisions when purchasing security technology.

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United States Environmental Protection Agency

NHSRC Research Projects

Multi Use →
- Homeland Security
- Cross agency
- "Normal" Environmental Operations

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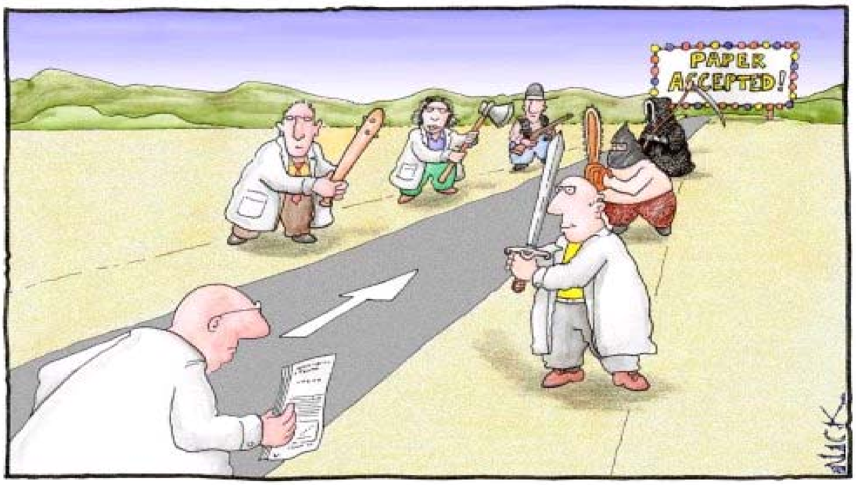
NHSRC Products

- **125 reports and journal articles since 2003 (including classified)**
- **Results presented many other ways—stakeholder meetings, symposiums, workshops, etc.**
- **Products and research plans receive rigorous quality reviews**



Most scientists regarded the new streamlined peer-review process as 'quite an improvement.'

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2. Validation Topics

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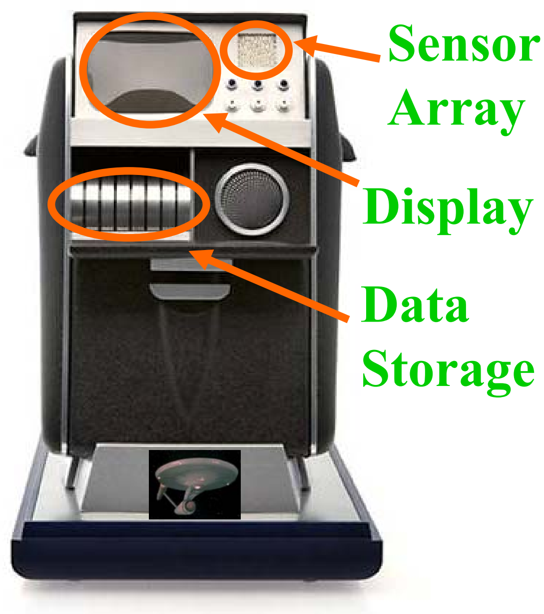
Validation Topics

- **Desirable characteristics of DRM/DRI**
  - Performs well
  - Intuitive data
  - Reliable
  - Long lasting
  - Easy to use and maintain
  - Cheap (inexpensive)
  - Easy to understand baseline in different situations
  - Etc



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Validation Topics

Definitions of Validation

- **Validation**: 'Confirmation by examination and provision of objective evidence that the particular requirements for a specified intended use are fulfilled.' [ISO 17025 Rule 5.4.5.1]
- **Method Validation**: The process of establishing the performance characteristics and limitations of a method and the identification of the influences which may change these characteristics and to what extent. [Eurochem 1998]
- **Instrument validation**: The process of establishing that an instrument at any given moment is able to perform according to its design specification This process might be achieved for example by means of calibration or performance checks. [Eurochem 1998]

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United States Environmental Protection Agency

Validation Topics

Validation Goal: Data that is reliable and relevant.

- **Reliability**: Is the data produced by instrument technically sound?
- **Relevance**: Is the data useful and interpretable to achieve the goal?

Many DRMs attempt to do both!

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United States Environmental Protection Agency

Validation Topics

Reliability: Standards for Manufacturing and Performance

- **Manufacturing Standards and Certifications (the easier part)**
  - ISO and related manufacturing standards
  - Technical certifications, e.g. CE, UL, etc.
- **Performance Criteria and Standards (much harder)**
  - Few and far between
  - Only for targeted cases
  - Department of Homeland Security Standards database has 3825 entries. A handful are for detectors, mostly radiation, toxic gases, and personal alert safety systems.

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Validation Topics

Reliability: Performance Characteristics (Metrics)

- The performance characteristics that should be validated will vary depending on the purpose of the procedure. Selecting and evaluating performance characteristics requires professional judgment.

- Four types of purposes:
  - Identification of unknown component(s)
  - Establishment of presence and/or absence of specified analyte(s) or classes
  - Quantitative analysis
  - Measurement of physical property

DRMs are designed to accomplish some or all these purposes. What performance characteristics are most applicable for each purpose?

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Validation Topics

Reliability: Performance Characteristics (Metrics)

Six basic characteristics for DRM data:

- Selectivity (e.g. in presence of interferents)
- Linearity (or other calibration model)
- Working range
- Limit of detection
- Limit of quantitation
- Accuracy (combination of precision and bias)

Some combination of characteristics may be applicable for each purpose. Which ones?

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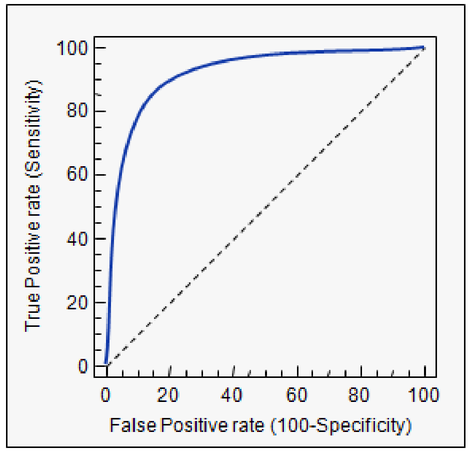
Validation Topics

Reliability: Performance Characteristics (Metrics)

- Characteristics are not independent, physically or statistically.
- It is necessary to understand the physical principles and apply an appropriate statistical test.
- Bayesian analysis and Receiver Operating Characteristic (ROC) curves are increasingly popular.



ROC curve (solid line)

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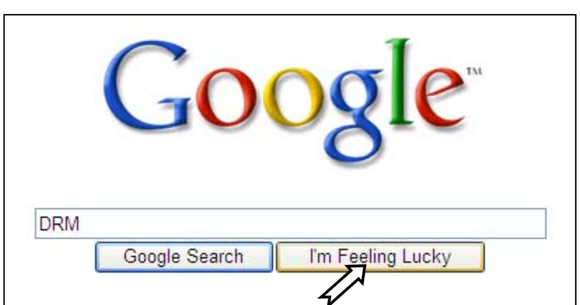
Validation Topics

Reliability: Some sources are not always reliable

- Sales reps/advertising
- Internet
- Non-independent trade magazines
- Television
- Etc



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Validation Topics

Reliability: Third Party Testing

- For evaluating DRM performance
- Ensuring comparability between detector results
- Several types testing programs in existence
  - Performance
  - Technical Competence of Instrument
- Different organizations have different approaches

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Validation Topics

Reliability: EPA Technology Testing and Evaluation Program (TTEP)

***Test*, *evaluate*, and *report* on the performance of homeland security-related technologies**

- building and outdoor area decontamination
- air, water, and wastewater treatment
- water security technologies
- detectors/monitors for air and water

Desired Outcome:

Informed decision making by our customers to detect, contain, decontaminate, and manage hazardous chemical, biological, and radiological materials purposefully or accidentally introduced into structures, facilities, drinking water systems, or the environment.

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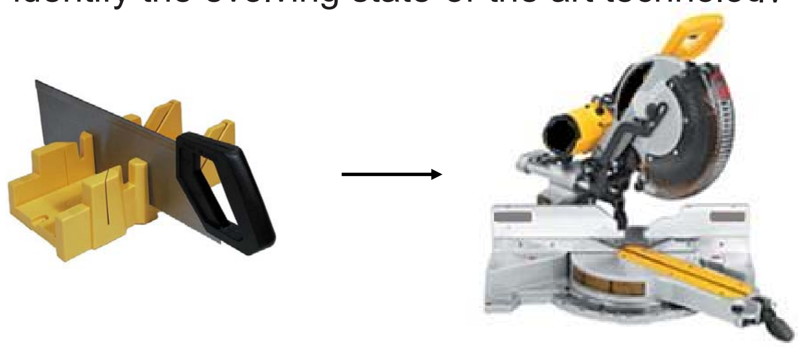
Reliability: Technology Testing and Evaluation Program (TTEP)

Rationale

- Our customers rely on technology to protect human health and the environment

- In the event of an intentional or unintentional contamination event, need:
  - Tools for detecting, monitoring, treating, decontaminating, etc.
  - Information to assess the nature and extent of an event
  - Information to monitor the progress of a clean up and verify completion

- Continuously identify the evolving state-of-the art technology



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Reliability: Technology Testing and Evaluation Program (TTEP)

Approach

- Primary focus is technology **testing** and **evaluation**
  - Test ***commercially available*** technologies using live agents under simulated field conditions

- Applied research and development testing
  - Determine if a technology not designed for homeland security-related uses could be applicable – stimulate development

- Information gathering
  - Information collection request (ICR)
  - Cataloging technologies that may be candidates for testing
  - Managing technology information to provide a ready source of information to emergency responders and consequence managers

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Reliability: Technology Testing and Evaluation Program (TTEP)

Components

- Technology Testing
  - Voluntary and involuntary testing of technologies
  - De-emphasize vendor involvement in testing
  - Testing to a range of desirable performance characteristics, requirements, or spec's
  - Use existing test/QA plans when possible
  - Testing with live agents

- Products
  - User-oriented products for procurement/application decisions
  - Brief summary report at conclusion of effort (10 to 20 pages)
  - Technology briefs, side-by-side comparisons offered when possible
  - Reports note problems/deficiencies in performance

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Reliability: Technology Testing and Evaluation Program (TTEP)

Components cont'd

- Technical Peer Review
  - Test plans and reports are reviewed by stakeholders and technical experts

- Stakeholder Involvement
  - Two stakeholder groups – Building Decontamination and Water Security
  - Environmental Response Technology Working Group (ERTG)
  - Taskforce on Research to Inform and Optimize CBR Response/Readiness (TRIO)

- Information Sharing
  - A single, quarterly newsletter containing information on all test and evaluation activities
  - Exhibiting at technical conferences and workshops

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Reliability: Technology Testing and Evaluation Program (TTEP)

What Technologies Types Have Been/Are Being Tested?

- Building and Outdoor Area Decontamination
  - Decontamination for chemical, biological, and radiological (on going)
  - Detection and monitoring to support decontamination (on going)
  - Air cleaning/filtration (completed)
  - Wastewater treatment (completed)

- Water Security-Related Technologies
  - Detection and monitoring (on going)
  - Sampling (completed)
  - Drinking water treatment (completed)
  - Water system decontamination (planned)

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Reliability: Technology Testing and Evaluation Program (TTEP)

Example: Air detectors

- Evaluate the performance of commercially available portable detectors for toxic industrial chemicals (TICs) and chemical warfare (CW) agents in air

- Target application is in guiding decontamination efforts, including:
  - identifying the nature of the contamination
  - identifying hot spots and uncontaminated areas
  - providing reliable response over a range of temperature and humidity conditions
  - minimizing false positives and false negatives caused by environmental interferences

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Detectors Evaluated

Bruker RAID-M

Cerex UV Hound

Environics ChemPro 100

Environics M90-D1-C CW Agent Detector

MSA Hazmat CAD Plus
formerly Microsensor Systems, Inc

SAIC S-CAD

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Reliability: Technology Testing and Evaluation Program (TTEP)

Example: Testing description for air detectors

- Evaluation of performance characteristics under robust conditions
  - Challenges with TICs and CWAs in air at hazardous levels (e.g., immediately dangerous to life and health, IDLH)
  - **Controlled test conditions over range of temperatures (5 to 40 ° C) and relative humidity (<20 to 80 %RH)**
  - **Interferent vapors that might be encountered at the scene of a building contamination event**

- Assessment of operational factors (ease of use, alarms, reliability, maintenance, battery life, consumables, cost)

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Reliability: Technology Testing and Evaluation Program (TTEP)

Example: Testing description (cont)

- Contaminants used in testing:
  - TICs: hydrogen cyanide (HCN), cyanogen chloride (ClCN), phosgene ($COCl_2$), arsine (AsH_3), and chlorine (Cl_2)
  - CWAs: Sarin (GB) and distilled mustard (HD)

- Interferences included latex paint fumes, air freshener vapors, ammonia floor cleaner vapors, exhaust hydrocarbons, and DEAE

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Validation Topics

Reliability and Relevance: Operator integration

- ***Validation = Operator + Instrument***

- **Operator**
  - Is the operator technically familiar with instrument?
  - Does the instrument produce unambiguous data?
  - Is the operator able to interpret the data if instrument can not, or is known to be ambiguous?
  - Does the operator know if the instrument is producing ambiguous data?
  - Has the operator changed?
  - Is the new operator trained?

- **Instrument**
  - What is the instrument actually doing?
  - Does instrument perform as promised?
  - What do those results mean?

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EPA United States Environmental Protection Agency

Validation Topics

Relevance: Validation of Entire Process, not just instrument component

- **Training is key component to validate operator**
  - Instrument operation
  - Data Interpretation

- Much training currently is focused on hazard/risk recognition, avoidance, or remediation

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EPA United States Environmental Protection Agency

Validation Topics

Relevance: Training Example-- Field Screening Workshop

Goals

- Identify the capabilities and limitations of field analytical instruments and tools that Hazmat teams may already possess, particularly for potential application to water contamination scenarios

- Understand how to interpret the results from field screening. Identify strategies for increasing the reliability of the results of field screening

- Understand the application of field screening with respect to reporting these results for all kinds of HAZMAT scenarios

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Validation Topics

Relevance: Training Example-- Field Screening Workshop

The following organizations helped contribute to the contents of this workshop:

- United States (U.S.) Environmental Protection Agency (EPA): National Homeland Security Research Center/Water Infrastructure Protection Division and National Enforcement Investigations Center
- U.S. Department of Justice (DOJ): Federal Bureau of Investigation, Hazardous Materials Response Unit
- U.S. Department of Defense (DoD): Civil Support Teams, Technical Escort Unit
- City of Cincinnati
- City of Denver

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Validation Topics

Relevance: Training Example-- Field Screening Workshop

Workshop Format

- 6-8 hr workshop
- Target audience: HAZMAT responders
- Target instructors: To Be Determined (TBD)
- "Beta Version"- draft
- Two trial sessions: Denver and Cincinnati
- Four "Modules"

Module 1: Introduction
Module 2: Field Screening Considerations
Module 3: Results and Interpretation, Especially for Water
Module 4: Field Screening Exercises

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3. Validation Related Needs

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Validation Related Needs

Technical

- Technological revolution
- Technological evolution
- Getting most out of current technology -- software
- How does the instrument actually operate, particularly the software? – manufacturers won't often tell
- Standards for libraries and library software
- Standard for standards, e.g. what combination of performance characteristics are most applicable to each purpose?

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Validation Related Needs

Policy

- Standards linked to funding:
  - Operator integration into DRM validation
  - Validation test plans
  - Comparable statistical interpretation of results
  - Instruments and instrument software
  - Libraries and library software
  - Standards for specific applications

- "Safe" disclosure route for manufacturers for software and hardware

- Increasing inventiveness – helping companies understand their potential market

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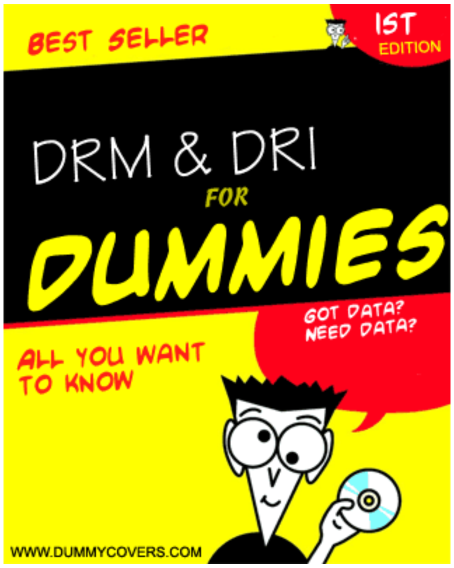
Validation Related Needs

Training

- Targeted at audience for specific application

- Stressing entire process
  - Instrument fundamentals
  - Detection Strategy
  - Sample prep
  - Data Collection
  - Data Interpretation
  - Reporting of Results



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Questions?

Matthew L. Magnuson
magnuson.matthew@epa.gov
513-569-7321
www.epa.gov/nhsrc

National Homeland Security Research Center
Cincinnati, OH; Research Triangle Park, NC; Washington, DC

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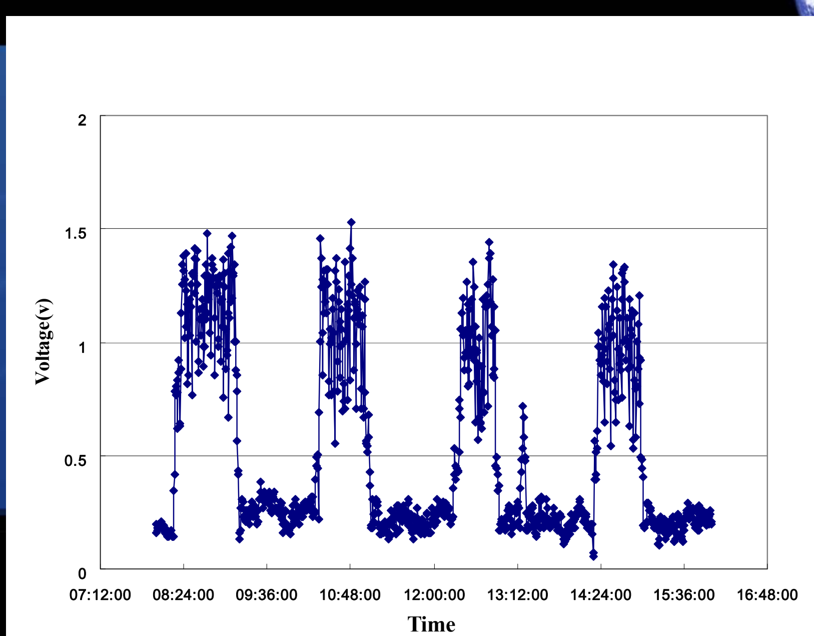
D.R.E.A.M.
WORKSHOP

Integration of Activity Through Position

Peng-Yau, Eric, Wang

National Central University, Taiwan
SWEETEK INC.

IOSH, TAIWAN



IOSH, TAIWAN

Introduction

- **We often want to know**
  - **Who are you ?**
  - **Where are you ?**
  - **How are you ?**
  - **What are you doing now ?**
  - **What's your exposed level ?**
- **Activity patterns associated with exposure levels are often important in the exposure assessment.**
- **Images are essentials in behavior analysis, accident investigations and hazard preventions.**

IOSH, TAIWAN

Current Methods

- **TAP methods**
  - ***Direct observation***
  - ***Questionnaire***
  - ***Activity daily record***
  - ***Video monitoring***
  - ***Infrared (IR) location system***
  - ***Global position system (GPS)***
- **Limitations**
  - ***Lack of accuracy***
  - ***No real time data***
  - ***Outdoor only***

IOSH, TAIWAN

What do we need?

- ***Real-time data***
- ***Precise location tracking (especially indoors)***
- ***Handy devices (light, long battery life)***
- ***Low cost and easy to use***

IOSH, TAIWAN

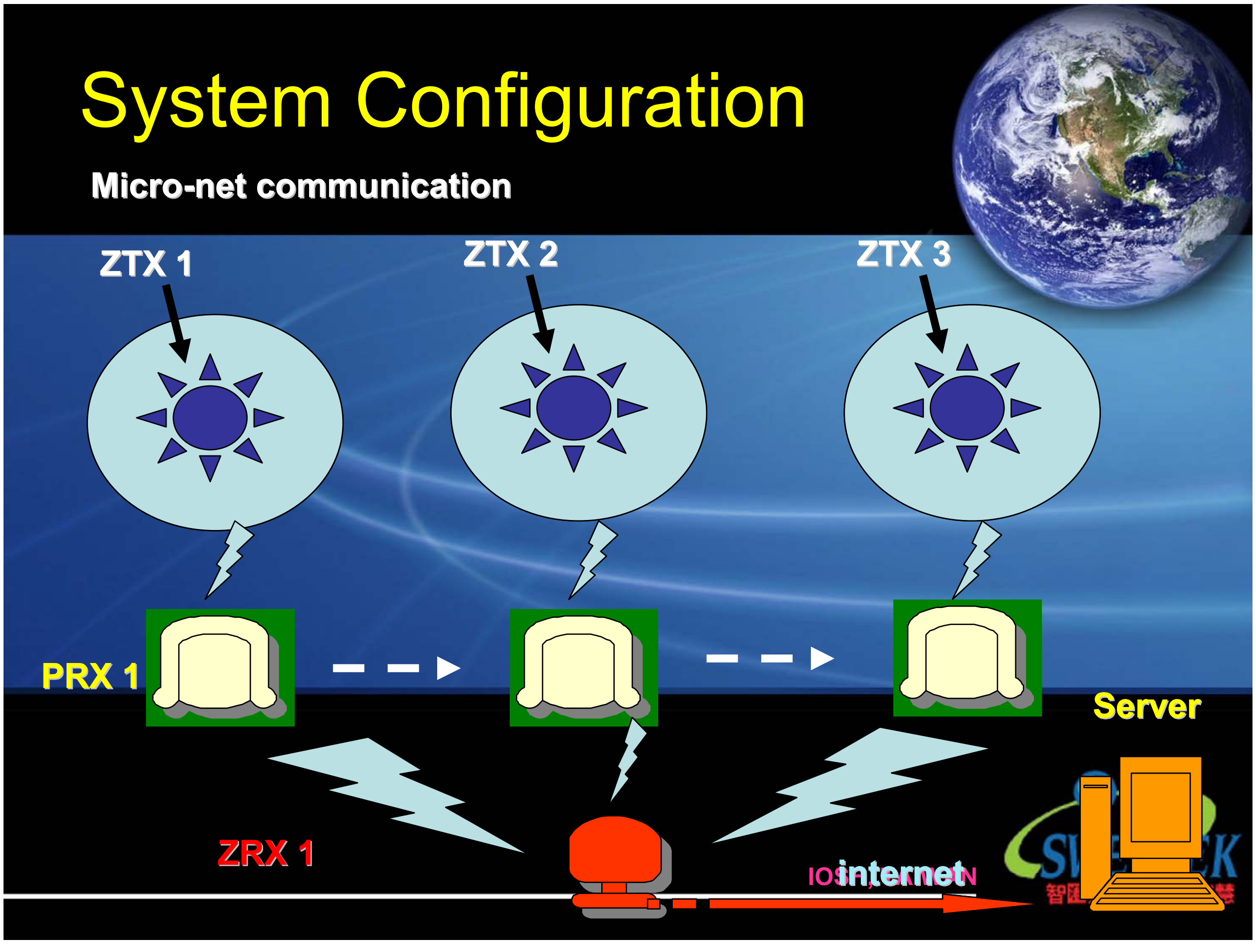
SWEETEK 智匯無線 無限智慧

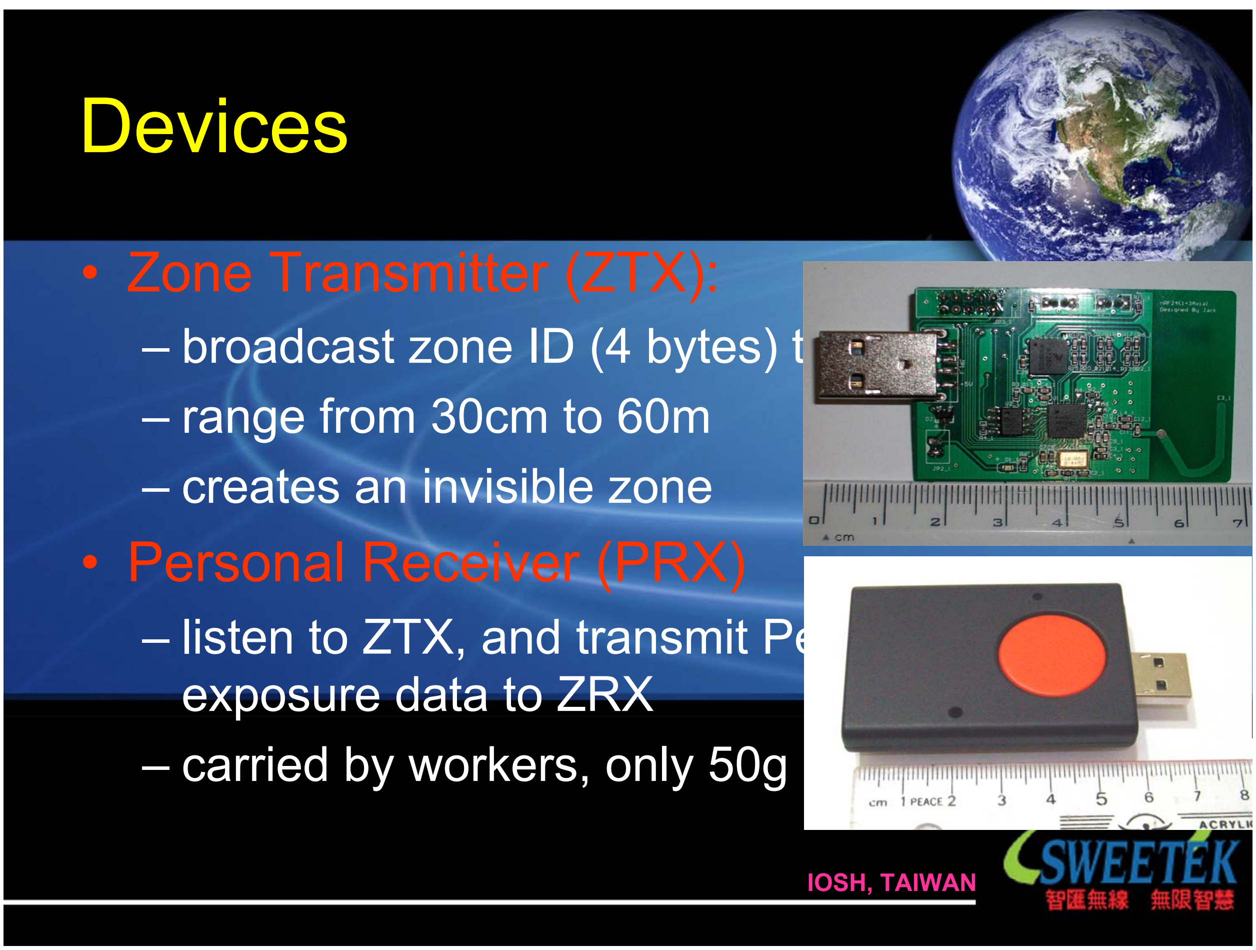
A New Approach

- **Locations** are determined based on wireless communications (Active RFID)
- **Activities** are recorded by digital video recorders only when workers are presented at the location.
- **Exposure levels** are monitored by proper sensors, such as noise meters or SnO_2 VOC sensors.
- **Data** are stored in either personal devices or servers.

IOSH, TAIWAN

SWEETEK 智匯無線 無限智慧


System Configuration
Micro-net communication
ZTX 1
ZTX 2
ZTX 3
PRX 1
Server
ZRX 1
internet


Devices
• Zone Transmitter (ZTX):
– broadcast zone ID (4 bytes) t
– range from 30cm to 60m
– creates an invisible zone
• Personal Receiver (PRX)
– listen to ZTX, and transmit Pe
exposure data to ZRX
– carried by workers, only 50g
IOSH, TAIWAN
SWEETEK
智匯無線 無限智慧

Devices

- Zone Receiver (ZRX)
  - Receive data from PRX and transmit them to a network along with MAC address
- Repeater (RPT)
  - Relay PRX data until reach
  - Range to 60m(2.4GHz modu
    (433MHz module)
- Field Display
  - Display position data and alarm

IOS

Devices

- Sensors
  - Chemical Sensor (SnO2)
  - Noise Meter
  - 3-axis Digital Accelerometer
- Video
  - IP-Based camera
  - Wireless camera
- Server
  - PC

IOSH

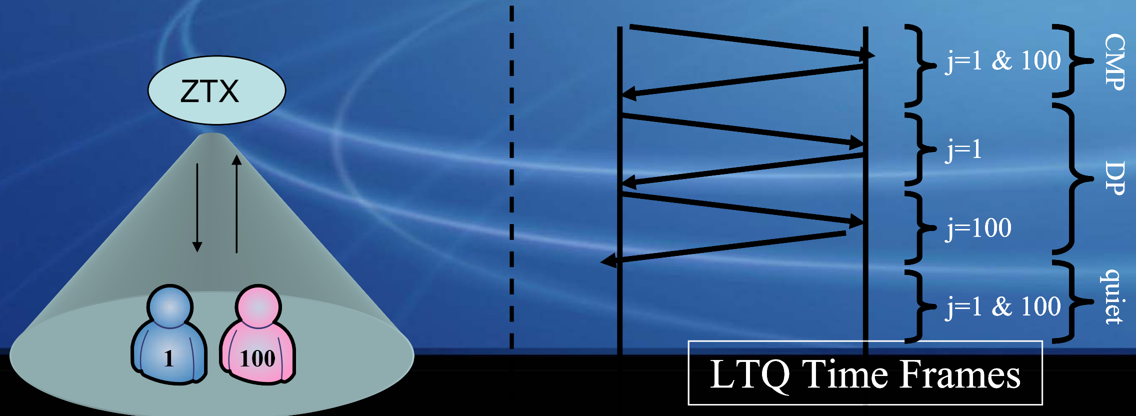
Challenges

- **Data Collision ?**
- **Roaming ability ?**
- **Power consumption ?**
- **Size and weight ?**
- **Installation and operation ?**

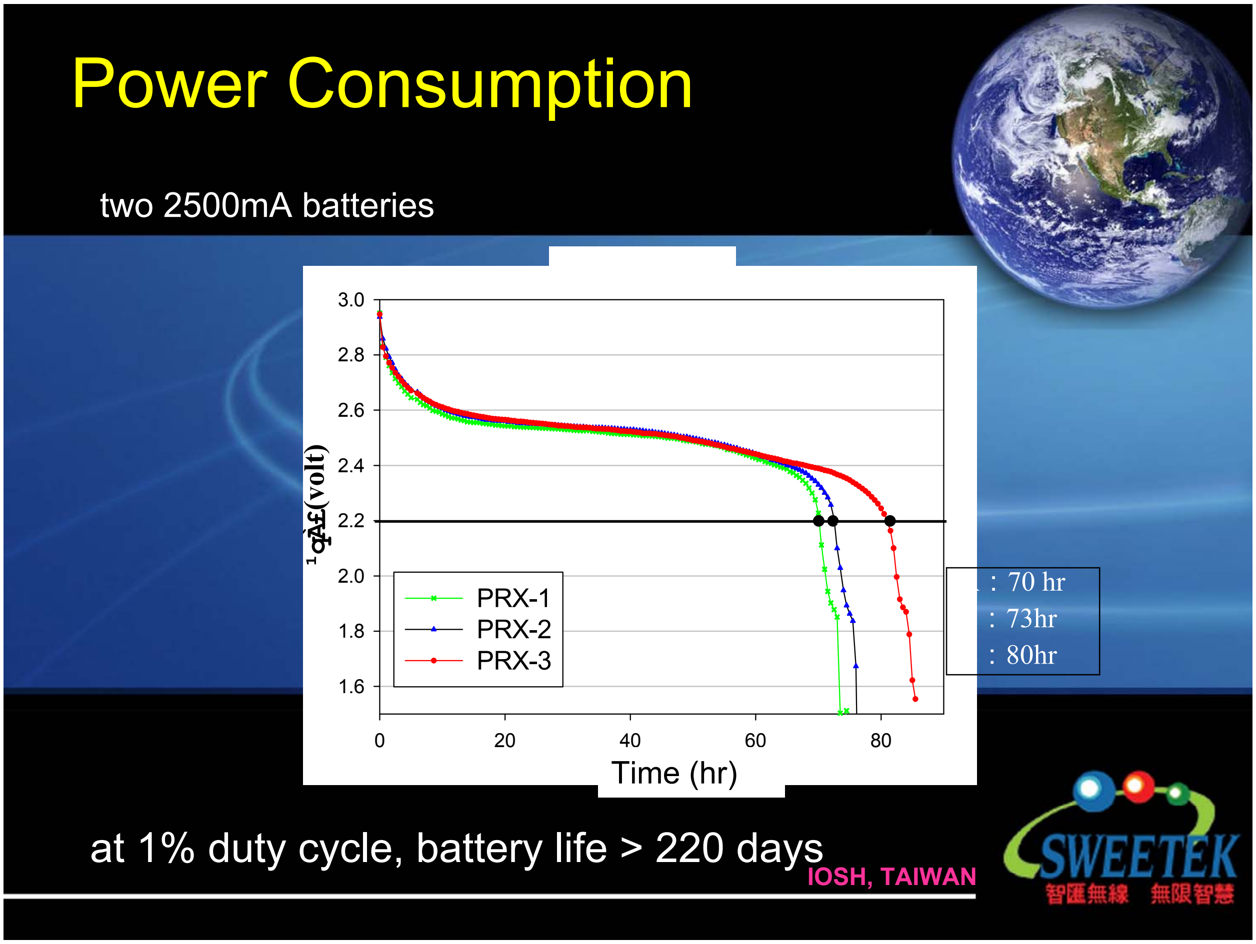
IOSH, TAIWAN

Avoid Collisions?

Listen-Talk-Quiet Protocol (LTQ)



IOSH, TAIWAN


Power Consumption
two 2500mA batteries
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
(volt)
PRX-1
PRX-2
PRX-3
0
20
40
60
80
Time (hr)
: 70 hr
: 73hr
: 80hr
at 1% duty cycle, battery life > 220 days
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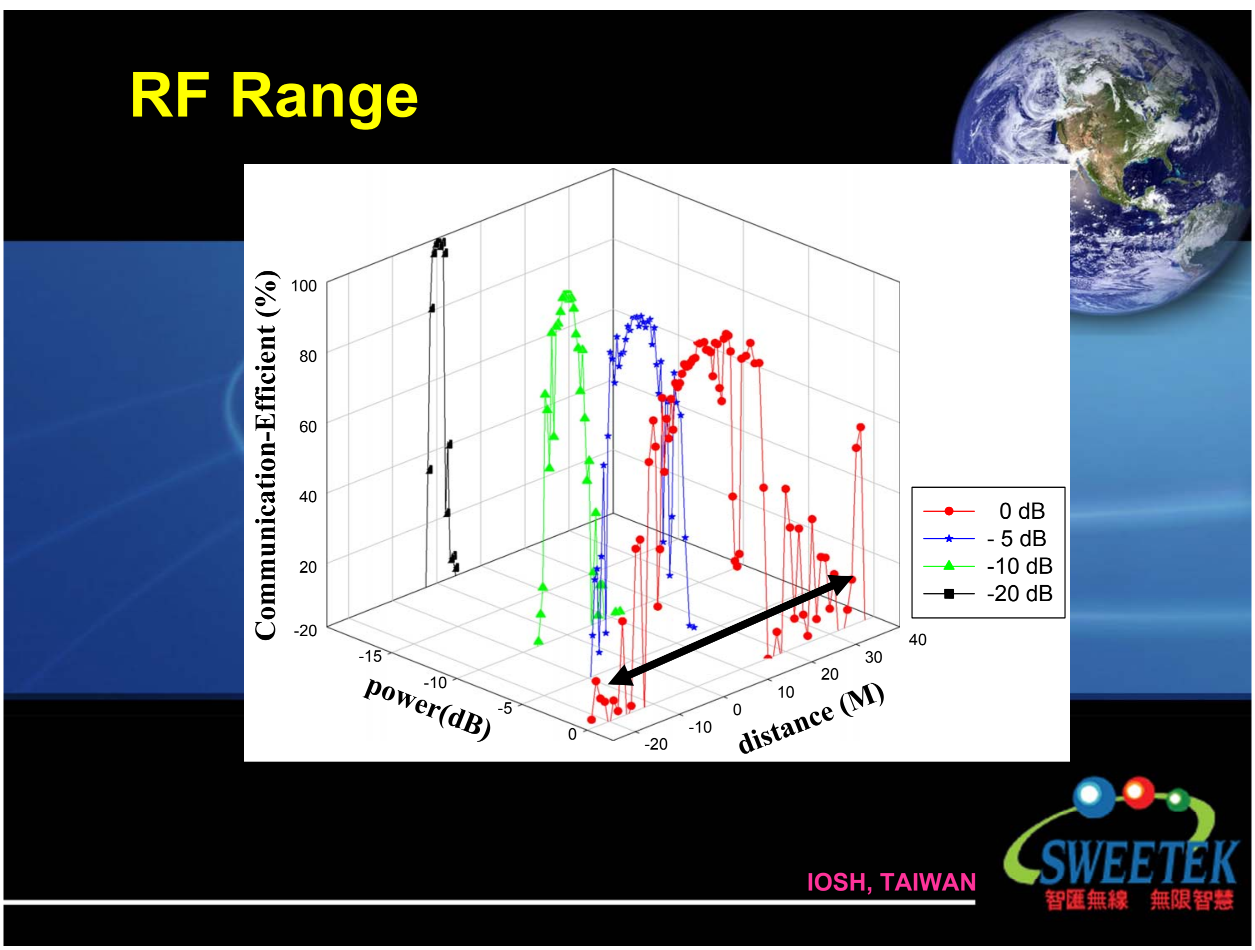
RF Range
Communication-Efficient (%)
100
80
60
40
20
-20
-15
-10
-5
0
power(dB)
-20
-10
0
10
20
30
40
distance (M)
0 dB
- 5 dB
-10 dB
-20 dB
IOSH, TAIWAN
SWEETEK
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Examples

- Real-Time Noise Exposure
- Activity Monitor in Confined Space

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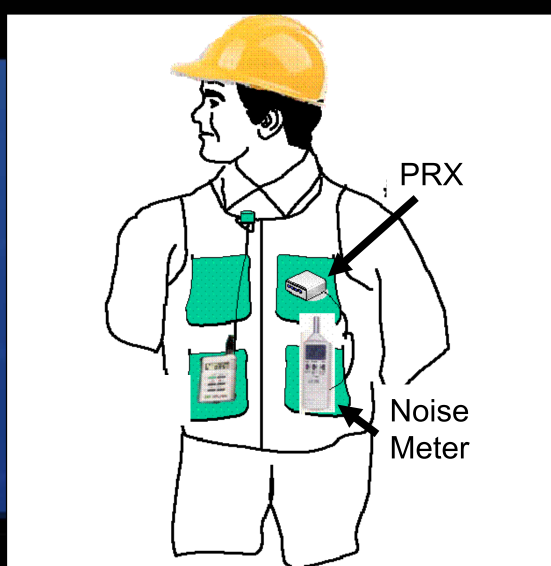
Noise Exposure Study



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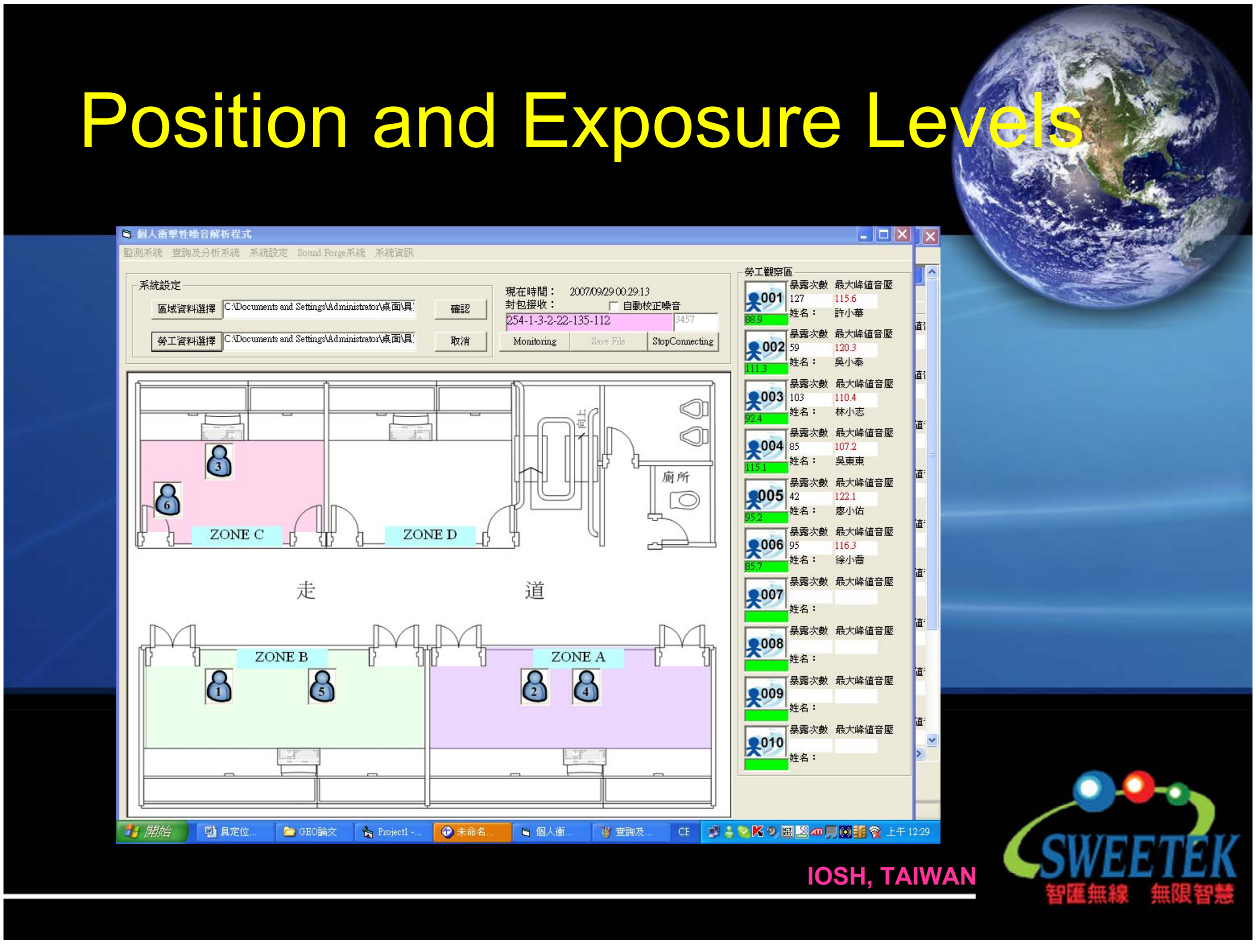
Position and Exposure Levels
ZONE C
ZONE D
走
道
廁所
ZONE B
ZONE A
Monitoring
Save File
StopConnecting
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SWEETEK
智匯無線 無限智慧


Activity Monitor in Confined Spaces
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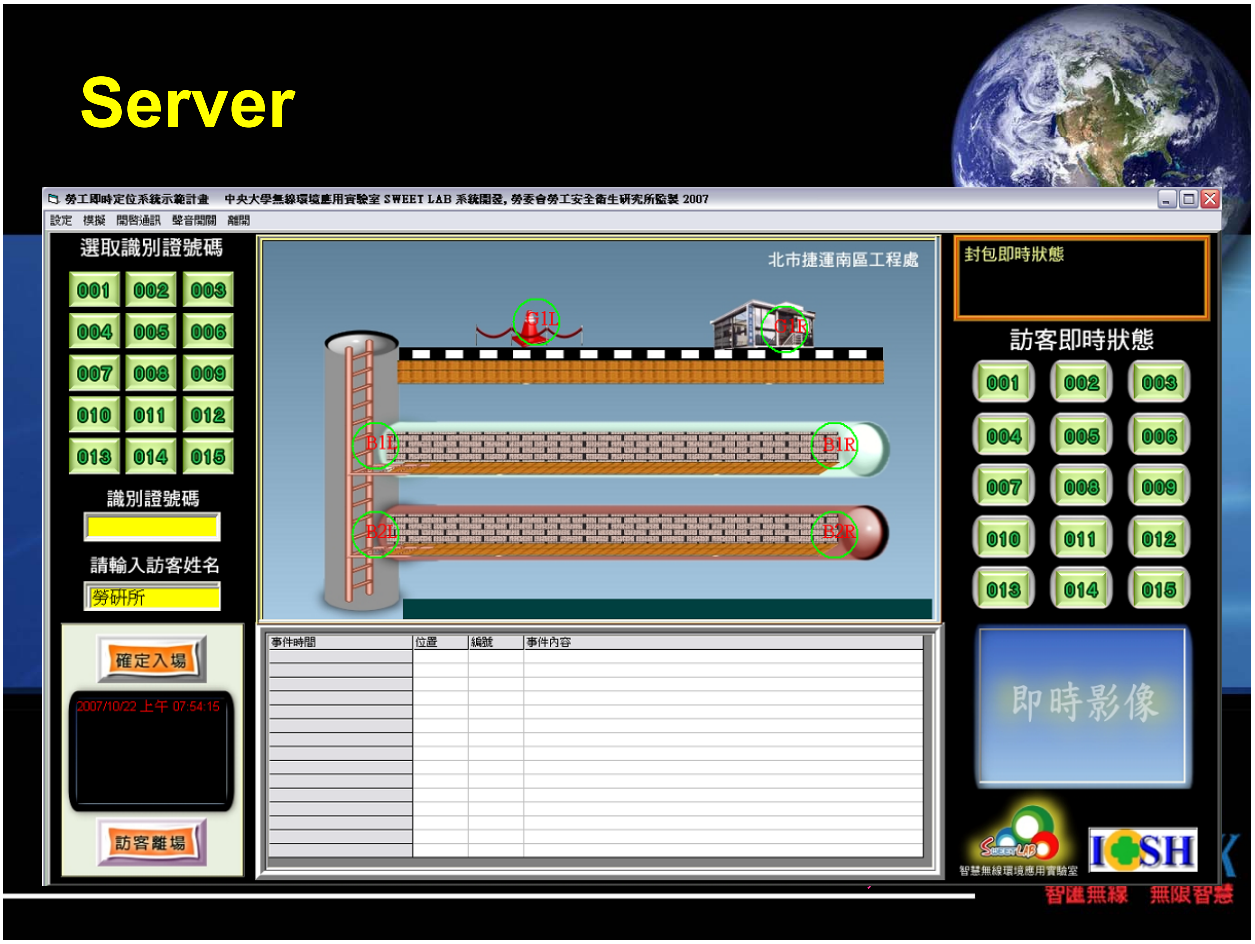
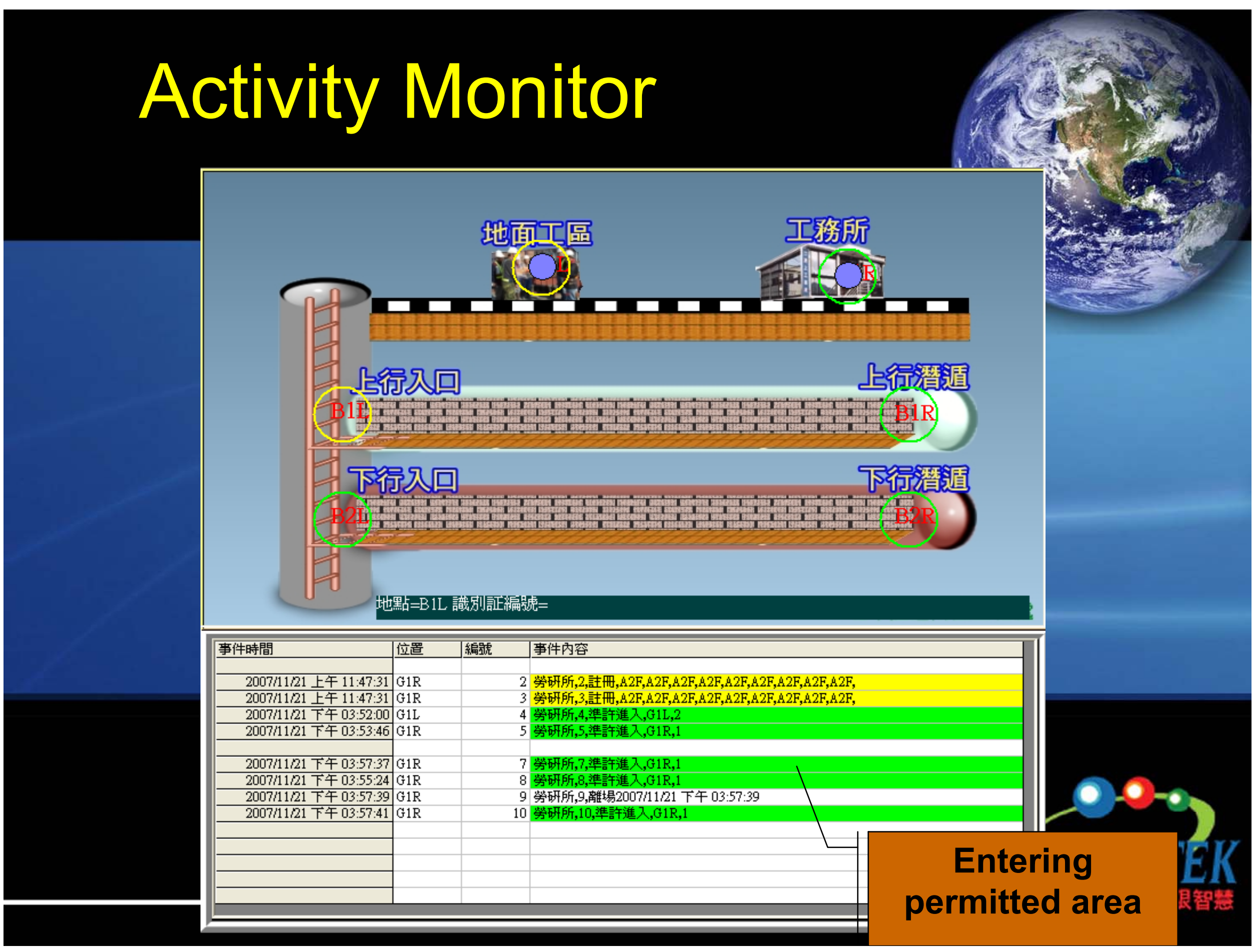
SWEETEK
智匯無線 無限智慧


Server
勞工即時定位系統示範計畫　中央大學無線環境應用實驗室 SWEET LAB 系統開發, 勞委會勞工安全衛生研究所監製 2007
設定 模擬 開啓通訊 聲音開關 離開
選取識別證號碼
001 002 003 004 005 006 007 008 009 010 011 012 013 014 015
識別證號碼
請輸入訪客姓名
勞研所
確定入場
2007/10/22 上午 07:54:15
訪客離場
北市捷運南區工程處
G1L G1R B1L B1R B2L B2R
事件時間 位置 編號 事件內容
封包即時狀態
訪客即時狀態
001 002 003 004 005 006 007 008 009 010 011 012 013 014 015
即時影像
智慧無線環境應用實驗室
I SH
智慧無線 無限智慧


Activity Monitor
地面工區
工務所
上行入口
上行潛道
下行入口
下行潛道
B1L B1R B2L B2R
地點=B1L 識別証編號=
事件時間 位置 編號 事件內容
2007/11/21 上午 11:47:31 G1R 2 勞研所,2,註冊,A2F,A2F,A2F,A2F,A2F,A2F,A2F,A2F,A2F,
2007/11/21 上午 11:47:31 G1R 3 勞研所,3,註冊,A2F,A2F,A2F,A2F,A2F,A2F,A2F,A2F,A2F,
2007/11/21 下午 03:52:00 G1L 4 勞研所,4,準許進入,G1L,2
2007/11/21 下午 03:53:46 G1R 5 勞研所,5,準許進入,G1R,1
2007/11/21 下午 03:57:37 G1R 7 勞研所,7,準許進入,G1R,1
2007/11/21 下午 03:55:24 G1R 8 勞研所,8,準許進入,G1R,1
2007/11/21 下午 03:57:39 G1R 9 勞研所,9,離場2007/11/21 下午 03:57:39
2007/11/21 下午 03:57:41 G1R 10 勞研所,10,準許進入,G1R,1
Entering permitted area

Field Test Results

Date	No. of pos. recorded by system	No. of pos. recorded by researcher
11/23/2007	371	374
11/27/2007	225	231
11/28/2007	470	473
11/29/2007	364	368
TOTAL	1430	1446
Success rate	98.89%	

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Field Test Results

Date	No. of path recorded by system	No. of path recorded by researcher
11/23/2007	36	36
11/27/2007	30	30
11/28/2007	44	44
11/29/2007	36	37
TOTAL	146	147
Success rate	99.32%	

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WHAT'S NEXT
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3D Monitor
VIS, Virtual Inspector System for IOHA2008. Design by IOSH & SweetLAB 2008
Config Search Simulation Open Com Port Sound Exit
Select VisitorID
Realtime Photo
1. Stand on purple feet
2. Enter Your Name
3. Unplug USB ID on your right side
4. Wear the helmet
5. Move to the left on one step for check
6. Check the LED information
IOSH
ID 1
VISITOR John
Sexuality Male Female
Realtime
Visitor Status
Visitor Photo
IN
OUT
Time Position ID Event
12:56 Virtual Insp 1 John, 1, Access allow, Virtual Inspector, 2
智慧無線環境應用實驗室
IOSH 勞工安全衛生研究所


Event Review
Realtime Photo
Visitor Status
Visitor Photo
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Virtual Tour
Adobe Flash Player 9
核心成果展示展 Exhibition Hall
RFID Virtual Inspector System
Hi.歡迎 Mr. Michael 先生
虛擬檢查員 Virtual Inspector
移動 => 檢查成功 => 移動 => 移動 => 移動
Developed by IOSH&NCU IOSH 勞工安全衛生研究所 INSTITUTE OF OCCUPATIONAL SAFETY & HEALTH
中央大學智慧無線環境應用實驗室 National Central University, Smart Wireless Environmental & Educational Technology.
LAB www.sweetlab.ncu.edu.tw
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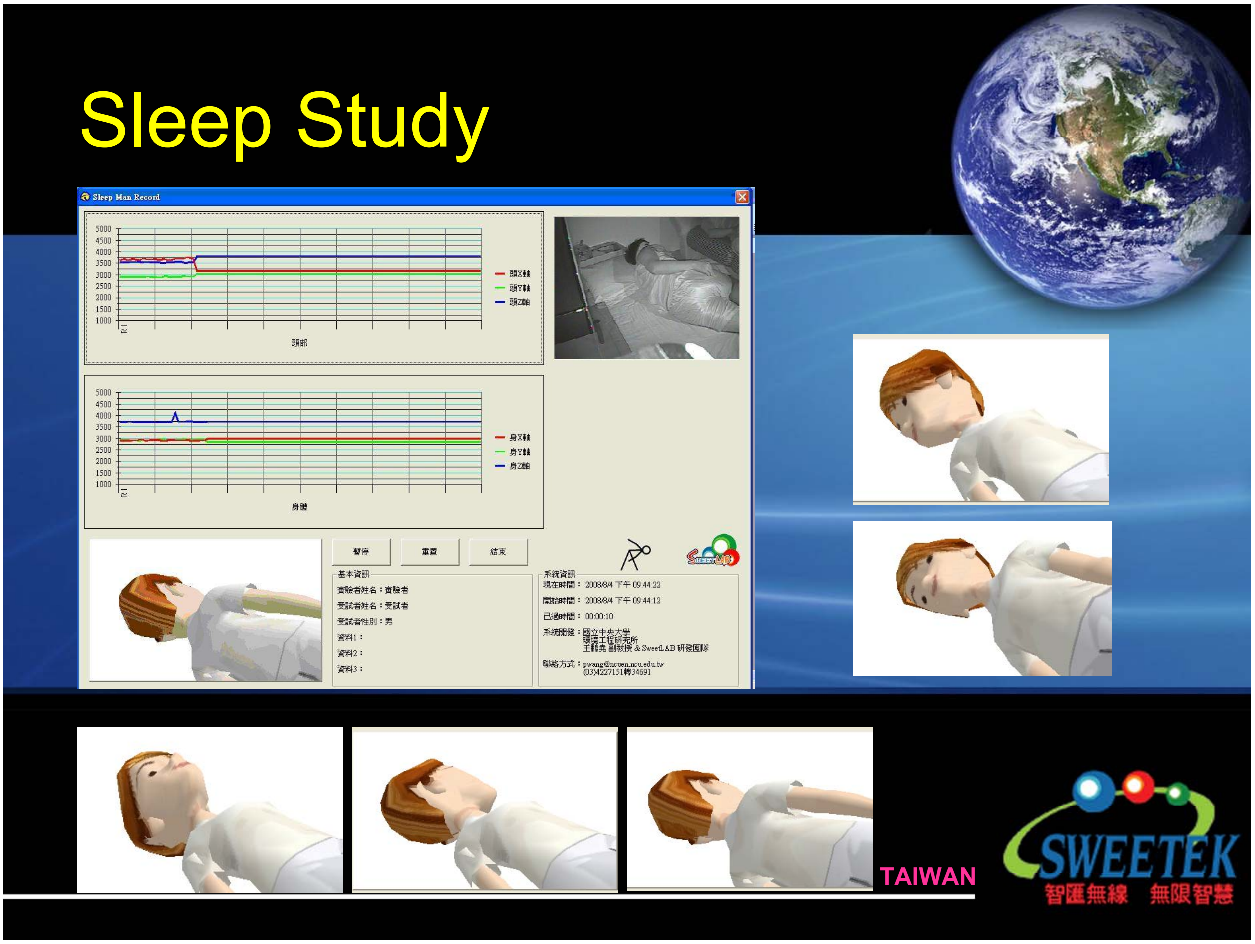

Issues

- Too many data, not only kill your HD, also could kill you.
- How to determine the useful information from different activity patterns?
- Safety or privacy? which comes first?

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- Special thanks to the IOSH,Taiwan and Mark Shih for his non-stop sponsoring of this research for a decade.
- Thanks to Dr. Harper for bring me here

- THANK YOU FOR YOUR ATTENTIONS !

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D.R.E.A.M.
WORKSHOP

Experiences with Direct Reading Instruments for Exposure Assessment

William A. Heitbrink Ph. D. CIH
Associate Professor
Occupational and Environmental Health
The University of Iowa.

Background

- Method: Review how direct reading instruments have impacted study findings.
- Objective: Provoke discussion.
- Used mostly direct reading instruments for aerosols.

Instruments used during field trials.

- Aerosol photometer
- Optical particle counter
- Condensation particle counter
- Surface area monitor
- Photo-ionization detector
- Flame ionization detector.

Optical aerosol Instruments.

- Textbooks note that response varies with :
  - Optical properties
  - Size
  - Shape
  - Wave length of radiation
- Response not directly related to mass concentration
- Quick response time

Aerosol Photometer Response Varies With Aerosol	
Aerosol Type	**Response Factor C_{pDR}/C_{filter}**
Environmental tobacco smoke	**6.94 ± 0.88**
Rural background aerosol	**1.92 ± 0.73**
Diesel particulate matter	**0.62 ± 0.16**
Source: Benton-Vitz John Volckens (2008): Evaluation of the pDR-1200 Real-Time Aerosol Monitor . Journal of Occupational and Environmental Hygiene, 5: 353–359	

Heitbrink's perspective and biases.

- Instruments are used to understand how exposures occur.
    -Trade off quickness for accuracy
- Study how concentrations vary with time
    - Determine how process affects exposure
    - Identify tasks affecting exposure
    - Need good time resolution
- Study how concentration varies with location
    - Identify hot spots
    - Determine where controls are needed.

Review three recent studies involving:

- Wet abrasive blasting;
- Dust control for mortar removal; and,
- Concentration mapping in an engine plant.

Looking Across time – field evaluation of control measures for mortar removal

Work Practices Affected Exposure

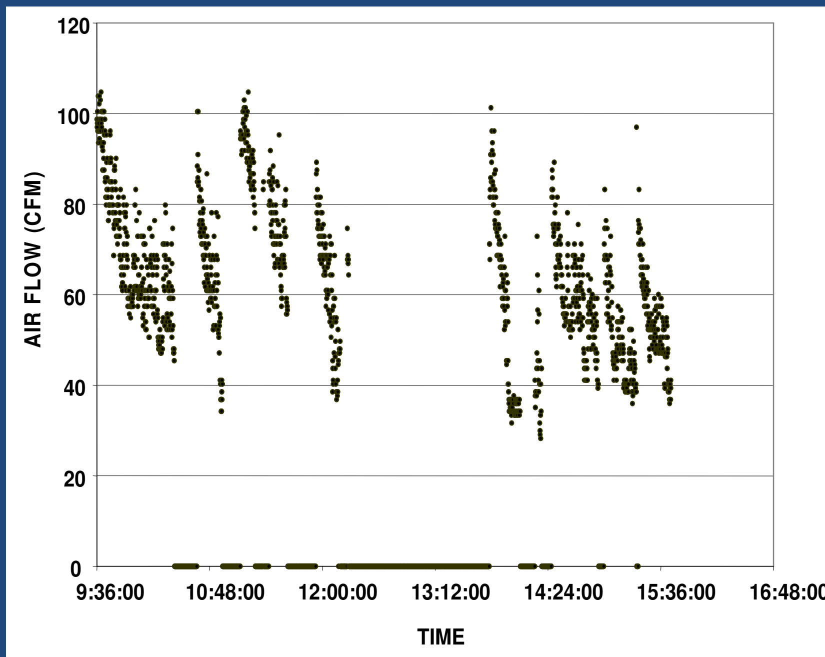
- Videotape worker grinding mortar and simultaneously log digitally:
  - Dust exposure with a real-time aerosol photometer.
  - Vacuum air flow with a data logging pressure transducer.
- Overlay exposure and vacuum flow rates onto video and observe work practices with resultant exposure and flow.

Video Exposure Monitoring illustrates the complexity of dust control during mortar removal

The horizontal joint under the exhaust take-off is missing. The mortar dust escapes the shroud and causes the workers dust exposure increase dramatically. Dust exposure is 20 mg/m³ (in purple on left) at 101 cfm (in red on right).

Routine horizontal cut. The mortar debris is being efficiently captured at a flow rate of 52 cfm and the worker's dust exposure is 0.15 mg/m³.

Maintaining air flow is an issue! Concentrations and these task-related independent variables may be cyclic as work can be repetitive. What does this mean for data analysis?



Note: air flow obtained From static pressure measured At inlet to vacuum cleaner motor. Fan curve used to convert static pressures to air flow.

Sometimes the dust plume does not go into the workers breathing zone!

Video Exposure Monitoring Results

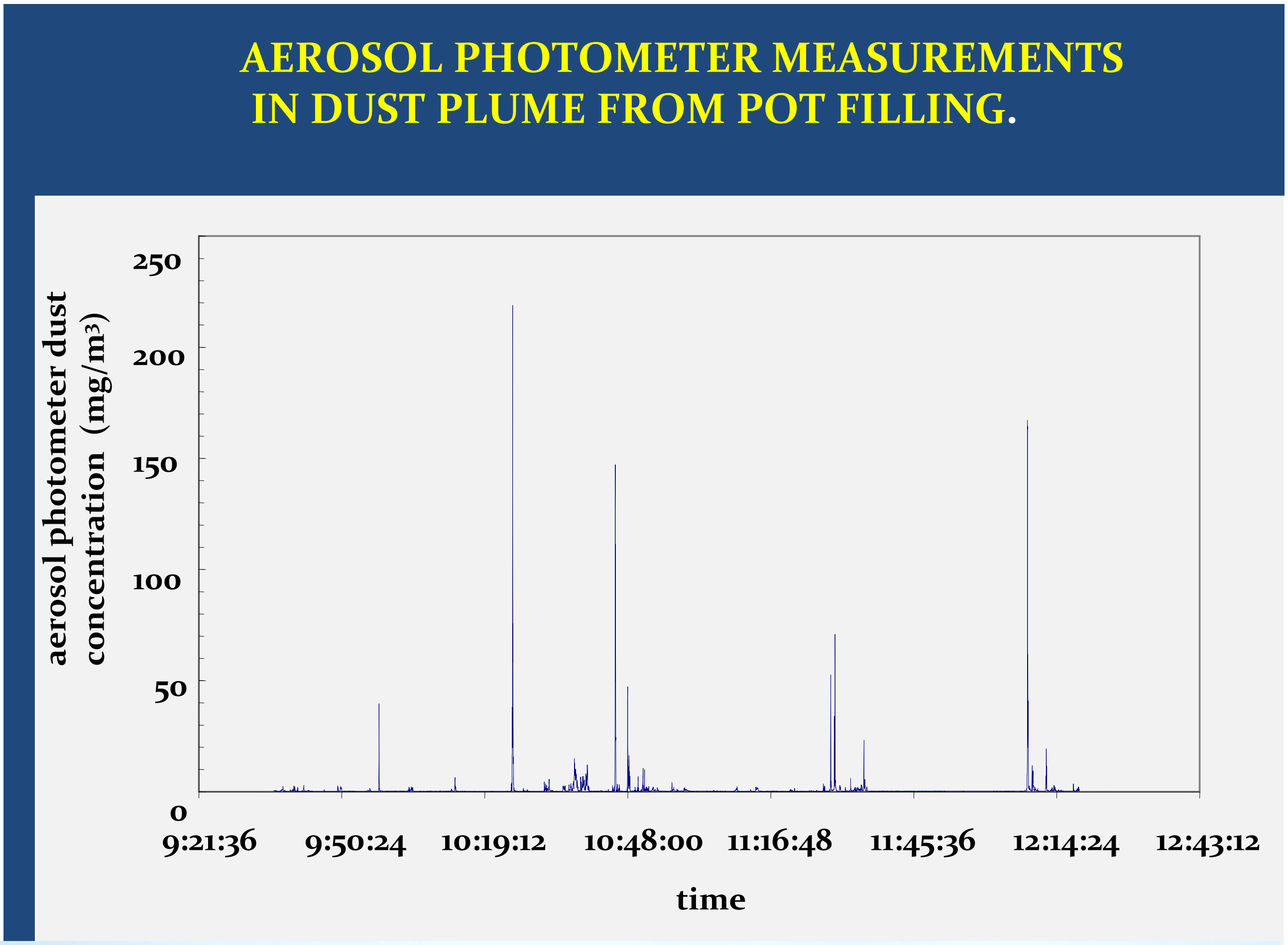
- Elevated dust exposures occur during:
  - Grinding blade entry/exit.
  - Repeat cut in same joint.
  - Very poor mortar conditions.
  - Confined space areas.
- Overtime, as vacuum bags loaded, flow rates decreased and dust exposures increased.
- Impacted practical guidance on dust control.

Studying planning and data analysis issues:

- Evaluate whether the differences in concentrations with task are really different?
  - Autocorrelation and statistical analysis?
  - Nyquist's sampling criteria?
- Dust plume does not necessarily flow toward the worker and instrument!
- How can one integrate process related variables with exposure measurements?
  - May be needed to develop control strategy.

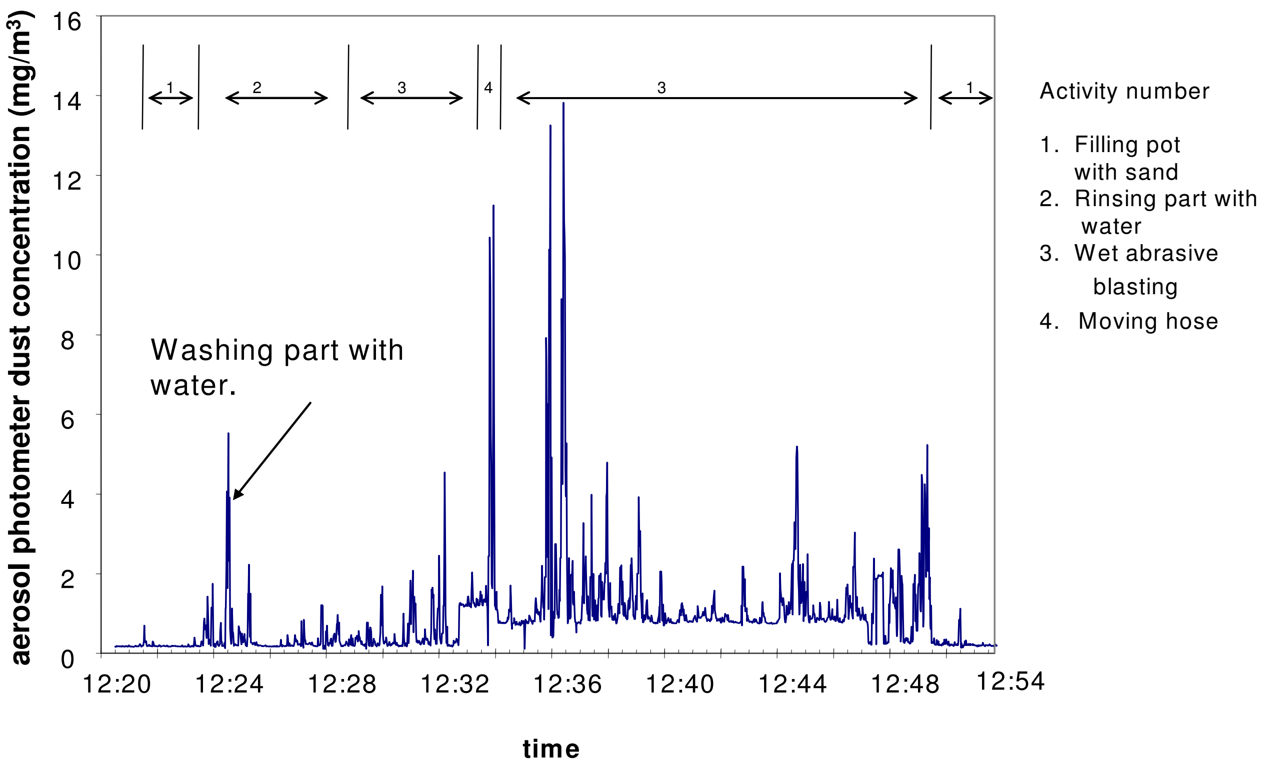
Looking across time-
Wet abrasive blasting

Filling abrasive blasting pot creates dust


AEROSOL PHOTOMETER MEASUREMENTS
IN DUST PLUME FROM POT FILLING.
aerosol photometer dust
concentration (mg/m³)
250
200
150
100
50
0
9:21:36
9:50:24
10:19:12
10:48:00
11:16:48
11:45:36
12:14:24
12:43:12
time


Wet abrasive blasting can be messy!
Abrasive stream contains sand and water.
Waste sand
Typical products are
Concrete building panels
Mud puddles

Non-specific responses are problematical! Are peak concentrations water, dust or crystalline silica?



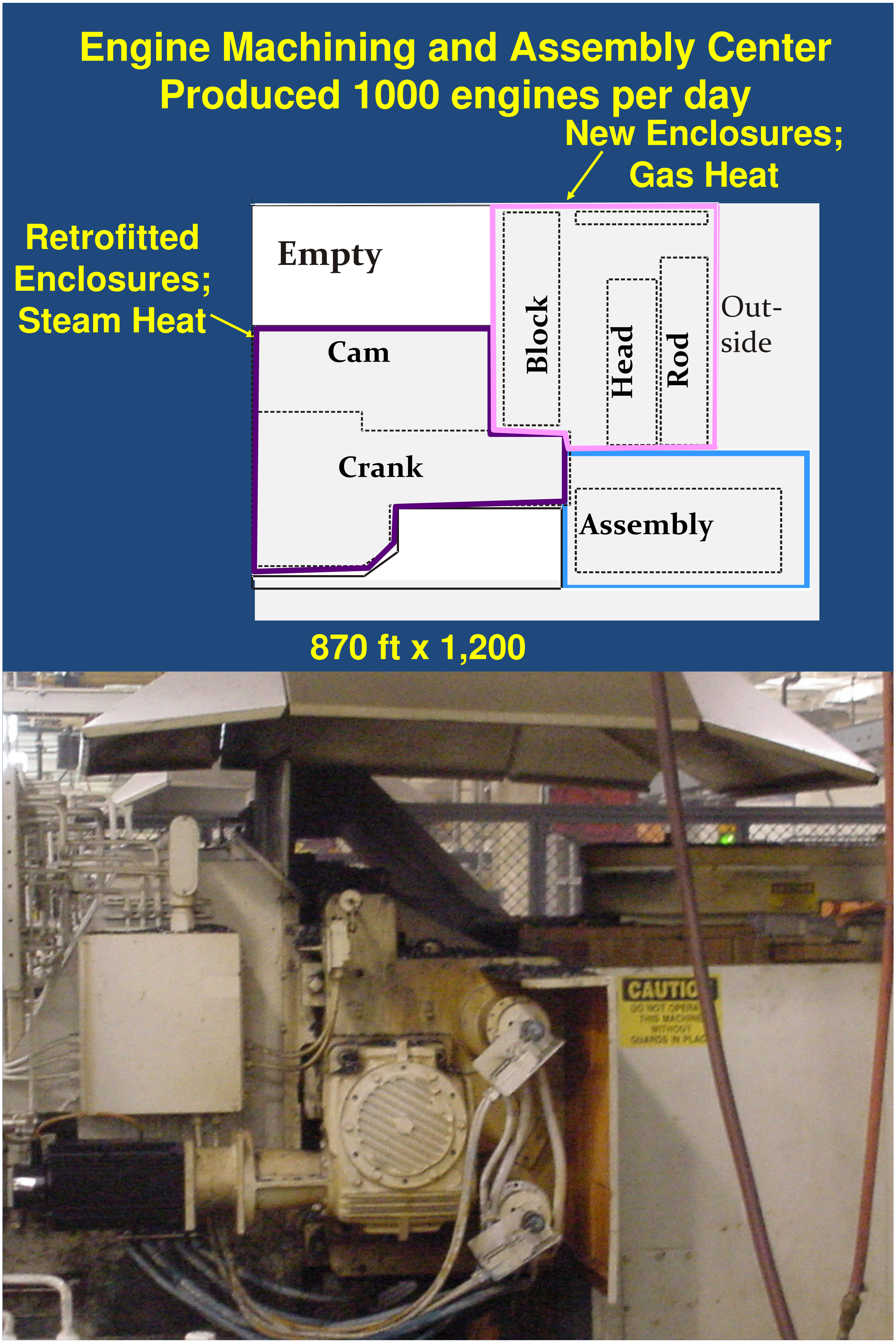
Wet Abrasive Blasting: Discussion

- Bin Filling is not big issue, the worker avoids dust plume.
- Is the aerosol photometer response caused by water mist or by aerosol? In preparing report, I ignored this result.
- Understanding instrument response is important so that one does not over react to results.

Looking across space-
Concentration Mapping

Mapping Procedures

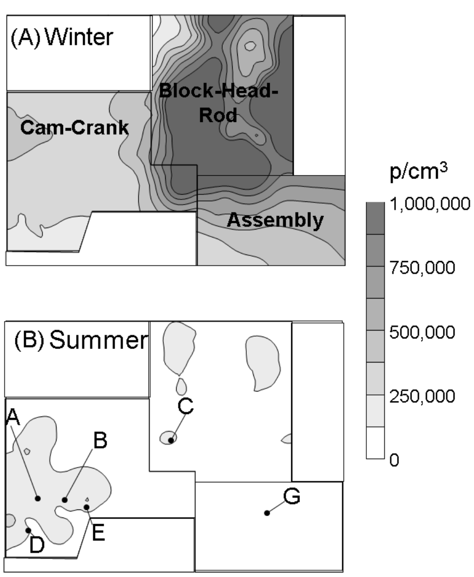
- Used condensation particle counter and optical particle counter to obtain concentrations.
- Sample one-minute at each position
  - Coarse grid (60 points)
  - Fine grid (200 points)
- Create aerosol maps


Engine Machining and Assembly Center
Produced 1000 engines per day
New Enclosures;
Gas Heat
Retrofitted
Enclosures;
Steam Heat
Empty
Cam
Crank
Block
Head
Rod
Out-
side
Assembly
870 ft x 1,200

Block-Head-Rod Lines had nearly complete enclosure appeared to completely control the mist generated by machining operations.

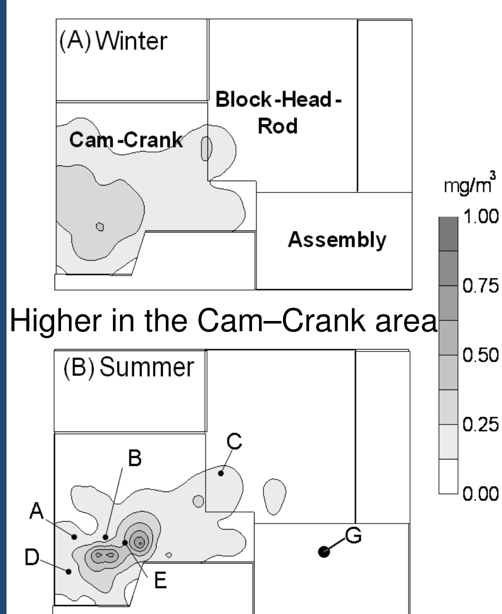
Different metrics - different picture of exposures.

A. Number concentration



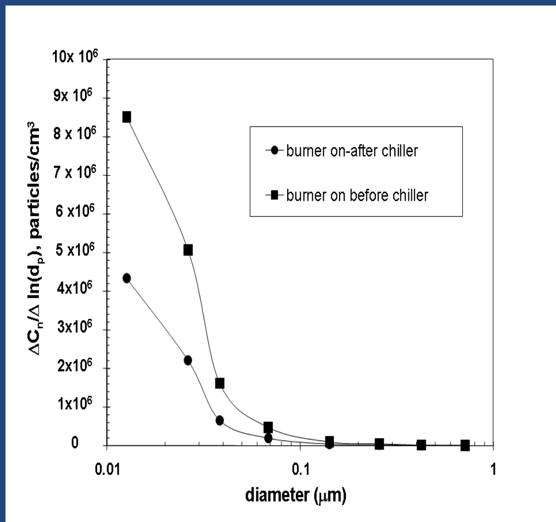
Varied significantly with season

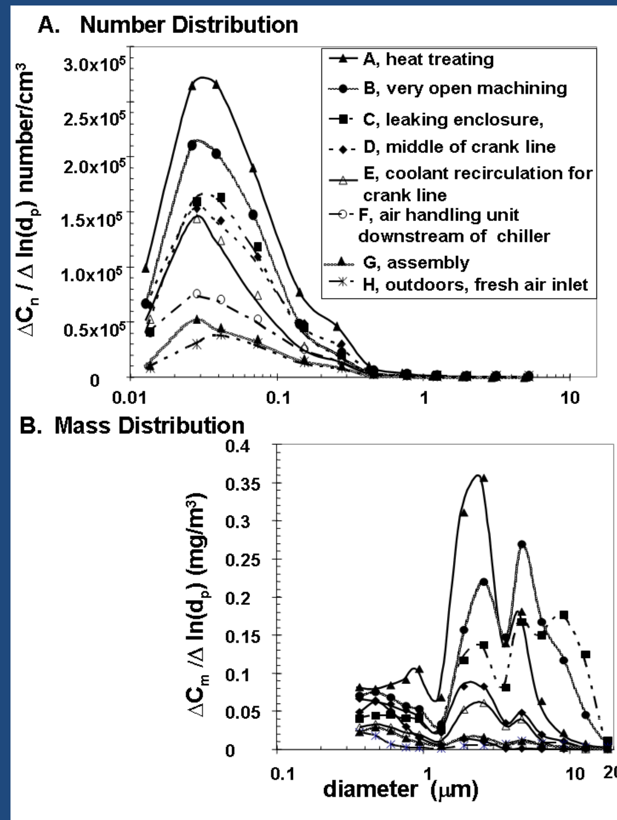
B. Mass concentration



Varied significantly with location

Size distribution information needed to interpret results.





Concentration Mapping: Data analysis/Data interpolation issues

- Spatial and temporal autocorrelation.
- Artifact generation with ELPI.
- Size distribution information needed to interpret data.

Advantages of optical instruments (non specific)

- Optical instruments are fast enough to follow industrial processes.
- Reasonably rugged.
- Generally, relative concentration measurements have not been problematical.
  - If aerosol varies, instrument response could lead into badly interpreted data.
- Can be used to devise control/interventions to reduce exposures.

Limitations of current optical instruments

- The response of the optical instruments varies with particle size and aerosol optical properties.
- Not useful for studying the association between health outcome and exposure.
- Personal TEOM has some commercial availability.
  - Is response time is too slow for some studies?
  - More related to mass than optical instruments

Future Direction Thoughts

- Develop applications for the use instruments as a problem solving tool:
  - Data analysis and study design procedures.
  - Problem solution-Intervention development.
  - Understand how to apply instrumentation
- Conduct research to understand the behavior of direct reading instruments.
  - Instruments will involve trade-offs between accuracy, response time, cost, and size.
  - Artifacts need to be understood.

Future Directions (Continued)

- Improve relationship between direct reading instruments and actual exposure metrics.
  - Exposure limits are based upon long-term health effects.
  - Develop application as a screening tool.
- Different instruments for different applications


D.R.E.A.M.
WORKSHOP

Issues Motivating the Collection of Occupational Exposure Data

S. M. Rappaport, Ph.D.
University of California, Berkeley
srappaport@berekeley.edu

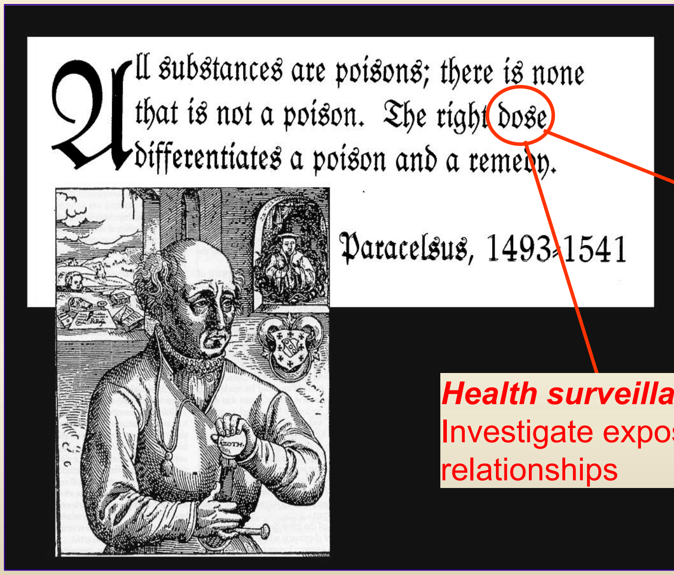
1

Topics

- Why measure airborne chemicals?
  - Hazard control v. health surveillance (epidemiology)
  - Air measurements v. exposures
- Evolution of air and exposure measurements
- Exposure variability and its sources
- How many measurements?
- If you build it will they come?
- Biomarkers of exposure

2

Why Measure Airborne Chemicals?



Hazard control: Setting and enforcing standards (OELs)

Health surveillance (epidemiology): Investigate exposure-(dose)-response relationships

3

Health Surveillance v. Hazard Control

- Health surveillance (epidemiology)
  - Primarily focus upon long-term effects (years-decades)
    - Investigate exposure-response relationships
    - Best with extensive long-term quantitative *exposure* data
- Hazard control
  - Focus upon both short-term and long-term hazards
    - Short-term: (seconds–hours, e.g., H_2S, CO, NO_2, NH_3) Require *air (not exposure) measurements in some cases*
    - Long-term: (years-decades, e.g., benzene, PAHs, asbestos, heavy metals) Require extensive long-term *exposure* data

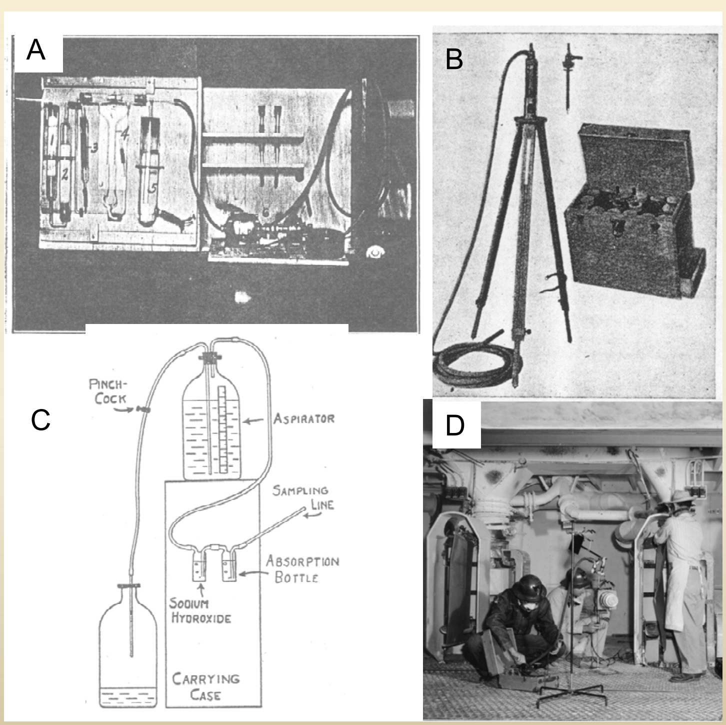
4

Evolution of Air and Exposure Measurements

Type	Air /Exposure	Time frame	Weight (g)	Assay
Area	Air	1920 - present	>1000	Lab
Breathing zone	Exposure	1940 - present	100 - 1000	Lab or direct
Personal	Exposure	1960 - present	10 - 1000	Lab or direct
Direct-reading (hand-held or personal)	Air or exposure	1980 - present	1 - 1000	Direct

5

Area Sampling: 1920s-Present (Air measurements not exposures)

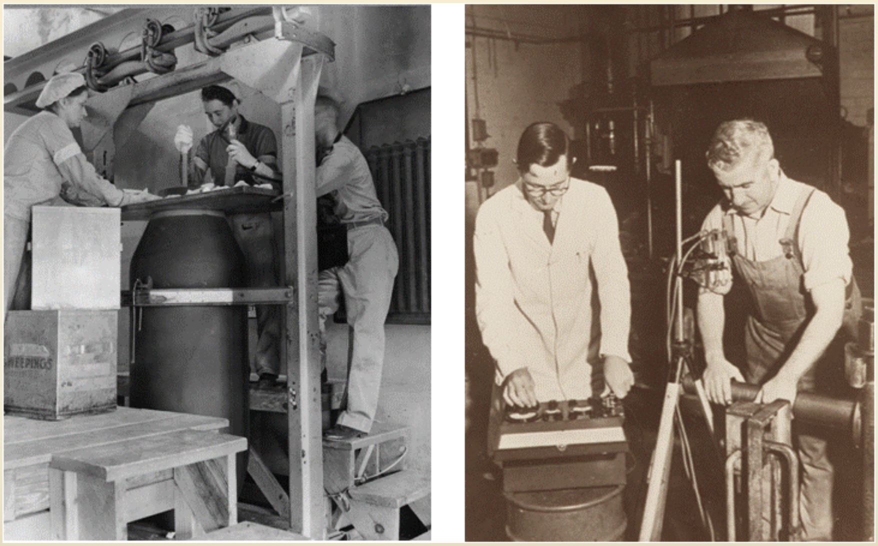


A: Collection of benzene by adsorption on charcoal about 1926 (Greenburg, 1926).
B: Greenburg-Smith impinger used for dust sampling about 1930 (Drinker and Hatch, 1936).
C: Collection of benzene by aspiration and absorption in acid about 1928 (Smyth and Smyth, 1928).
D: Collection of asbestos with a high-volume sampler and a cascade impactor about 1953 (Photograph courtesy of R. Herrick).

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

6

Breathing-zone Sampling: 1940s – Present (Moving from air measurements to exposures)

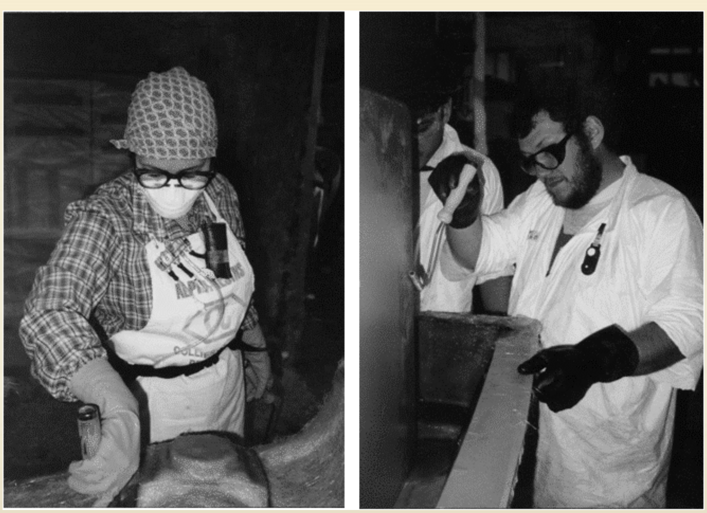


Two examples of breathing-zone sampling. Left: sampling with a midget impinger of explosive vapors (probably nitroglycerine) at an ordinance plant - USA (1943). US PHS . (Photograph courtesy of R. Herrick). Right: Benzene sampling with an explosimeter and silica gel tubes during manufacture of mechanical seals - UK (1950). (Photograph courtesy of R.J. Sherwood).

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

7

Personal Sampling: 1960s-Present (Exposure measurements)



Personal samplers to measure styrene, styrene oxide and MEKP in the reinforced-plastics industry- USA (1986). Left: active sampling with sorbent tubes and micro-impinger; Right: passive sampling with activated carbon (styrene and styrene oxide only).

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

8

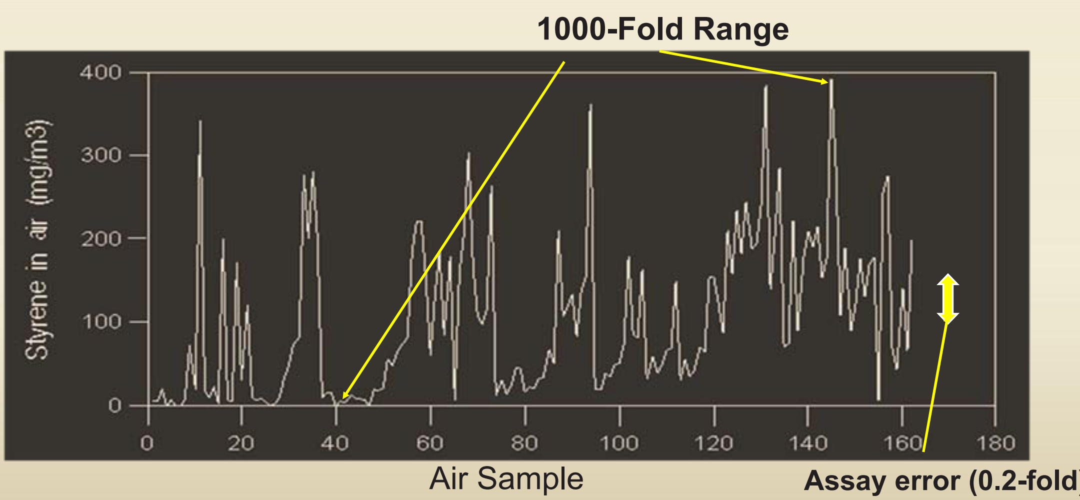
Direct Measurements: 1980s – Present (Air measurements or exposures)

Hand-held devices (air measurements)

Direct-reading personal monitors (exposures)

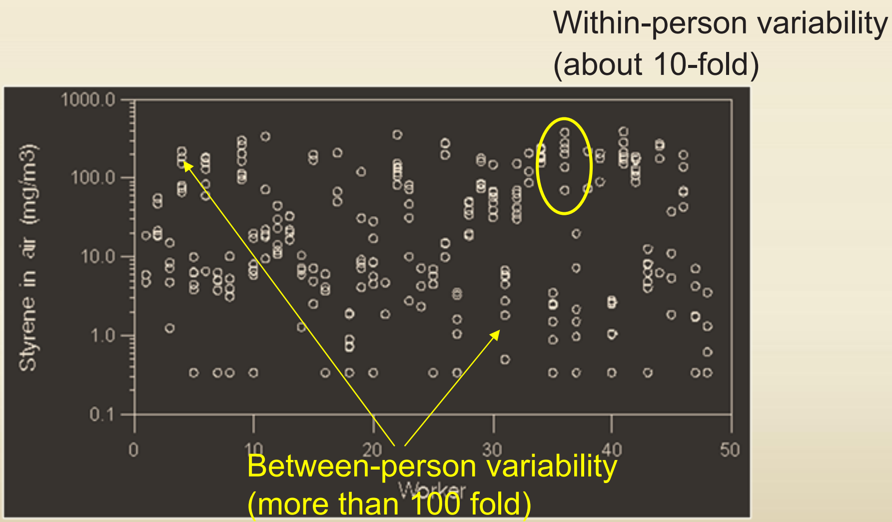
Exposure Variability

Styrene levels in a boat factory (162 personal measurements - 1986-87)



Data from: Rappaport, *et al. Cancer Res*, 56: 5410-5416 (1996)

Within- and Between-Worker Variability



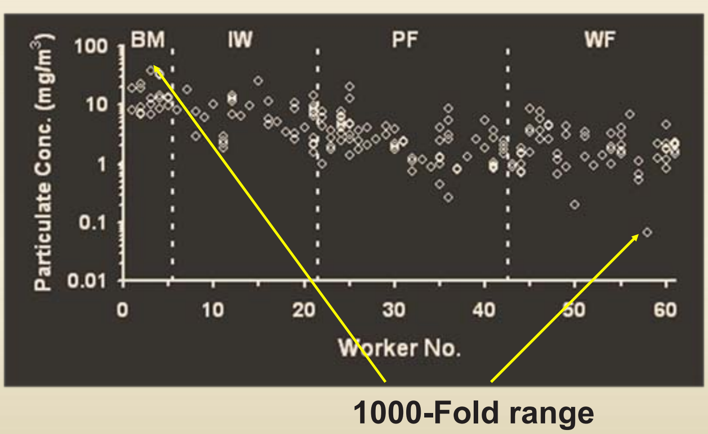
Data from: Rappaport *et al., Ann. Occup. Hyg.* 43:457-469, 1999

11

Exposure Variability

Welding-fume exposures among construction workers

(198 measurements from 62 workers in 4 trades – 1996-97)



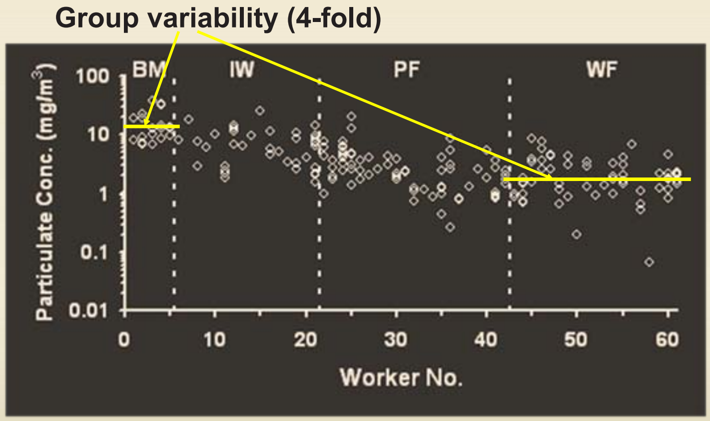
Data from: Rappaport *et al. Ann. Occup. Hyg.* 43:457-469, 1999

12

Exposure Variability

Welding-fume exposures among construction workers

(198 measurements from 62 workers in 4 jobs)



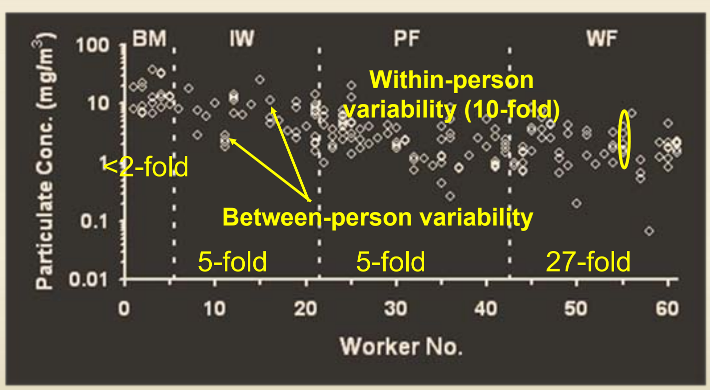
Data from: Rappaport *et al. Ann. Occup. Hyg.* 43:457-469, 1999

13

Exposure Variability

Welding-fume exposures among construction workers

(198 measurements from 62 workers in 4 jobs)



Data from: Rappaport *et al. Ann. Occup. Hyg.* 43:457-469, 1999

14

Determinants of Exposure to Welding Fumes (From fixed effect in mixed models)

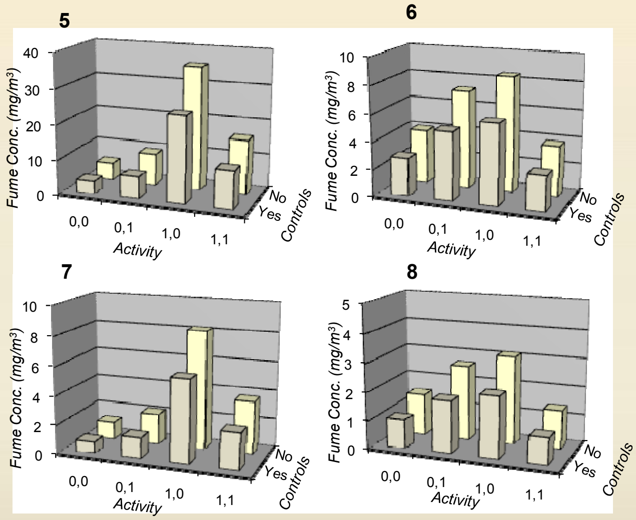
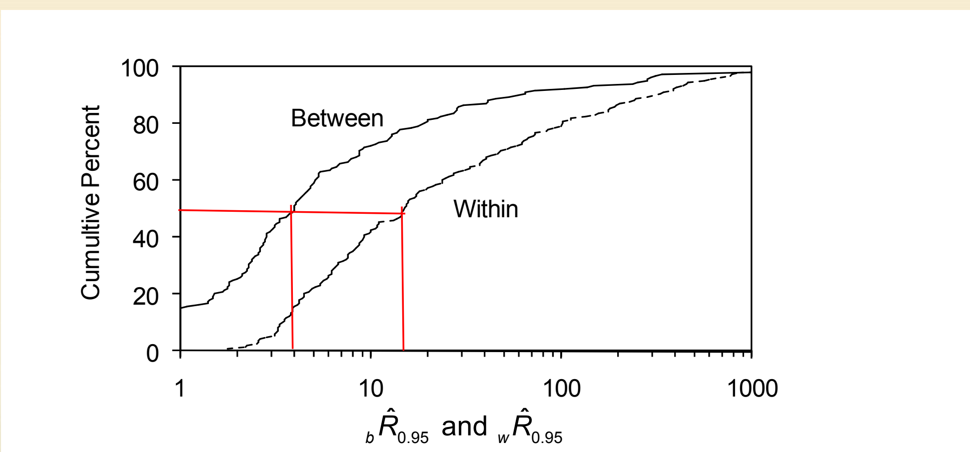


Fig. 7.6 Predicted mean exposures to welding fumes for Groups 5 - 8 (5=BM; 6=IW; 7=PF; 8=WF), based upon the model shown in Table 7.5. Activity (*IO, TW*): (0,0)=outdoor brazing/cutting; (0,1)=outdoor welding; (1,0)=indoor brazing/cutting; (1,1)=indoor welding. Controls consisted of local-exhaust or mechanical ventilation (*VE* = 1) and reduction of hot work to less than 50% (*CI* = 1). (Note that magnitudes of the y-axes differ across groups).

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

Variability Within and Between Workers



Between-worker = 4 fold: 95% of the workers in a given job group have mean exposure levels spanning a 4-fold range.

Within-worker = 15 fold: 95% of a typical worker's exposure levels vary 15-fold from day to day.

Rappaport and Kupper (2008) , *Quantitative Exposure Assessment, based upon work by Krommout et al. (1993)*

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Variability Within and Between Workers: Not a New Idea!

Within-person and between-person sources of variability in exposure levels were recognized as early as 1952 when Oldham and Roach applied ANOVA models to breathing zone samples of dust in British coal mines (Oldham and Roach, 1952). They made the following observation:

> "It was found that significant variation was occurring in the dust concentrations from one collier's experience to another's, and from one day to another in the same collier's experience." (Note that a 'collier' is a coal miner).

Yet, this finding was largely ignored at the time, and the issue of within-person and between-person variability was not revisited again until some 35 years later when personal exposure measurements became available in occupational studies (Kromhout *et al.*, 1987; Rappaport *et al.*, 1988b; Spear *et al.*, 1987).

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

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Why so variable?

Multiplicative effects of several variables

- Jobs (fixed)
- Time (fixed)
- Locations (fixed or random)
- Sources of contamination (fixed or random)
- Activities and equipment (fixed or random)
- Worker/source mobility (mostly random)
- Environmental conditions (mostly random)

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Implications of Exposure Variability

- Health surveillance (focus upon chronic health effects)
  - Many personal measurements needed to characterize *long-term exposures*
  - Longitudinal studies, evaluate variation within and between persons and across groups
    - Cannot assume all workers in a group are equally exposed
  - Advanced statistical models (mixed-effects models)
- Hazard control
  - Long-term hazards: same issues as above for health surveillance (repeated personal measurements, mixed modeling, etc.)
  - Short-term hazards: focus shifts to air levels/warnings of immediate dangers (*high air concentrations not exposures*)
    - Only most acutely toxic substances
    - Area sampling sufficient (e.g., confined spaces or at point of release)

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Sample Sizes for Air Measurements (1920s – 1950s)

- Focus upon health effects (exposure-response)
- Few professionals (mostly governmental)
- Cumbersome equipment
- No OELs
- Few studies but relatively large sample sizes (hundreds of measurements)

– Variability recognized

– Desired accurate estimates of average levels for each location or factory

- Classic study of Oldham and Roach (1952)

– 779 Breathing zone measurements (3-min) randomly collected repeatedly from Welsh coal miners

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Repeated Random Measurements

APPENDIX

RESULTS OF "RANDOM COLLIERS" SURVEY

Collier	Total Time Spent on Coal-face (min.)	Duration of Mid-shift Break (min.)	Thermal Precipitator Samples (No. of particles per ml. between 0·5 and 5·0μ)											
1	315	25	1,630	800	1,100	920	1,500	1,770	980	1,430	1,540			
	430	15	950	<100*										
2	—	—	*Collier no longer working at pit*											
3	350	20	<100	1,320	650	<100	<100	360	(<100)†	<100	220	180		
	365	20	800	1,180	1,130	880	430	430	390	360	460	440		
4	345	20	1,750	1,690	2,030	2,730	1,980	940	1,360	2,070	2,190	830	2,650	
5	—	—	*Collier absent on both occasions*											
	—	—												
6	270	20	570	<100	<100	(210)	310	740	2,000	520				
	335	25	240	170	450	560	320	280	(<100)	320	520	820	520	510
7	325	40	390	700	920	1,240	1,580	1,530	920	530				
	365	35	1,110	730	(<100)	(<100)	750	1,090	720	1,130	580	770		
8	300	25	580	770	470	(<100)								
	395	25	350	1,460	800	1,250	1,150	1,010	(<100)	860	920	760	840	

A portion of an appendix originally published by Oldham and Roach (Oldham and Roach, 1952). Each entry represents the dust level for a random 3-min sample obtained from a coal worker. Note that several such measurements were obtained from each subject on a given day.

Rappaport and Kupper (2008) 21
Quantitative Exposure Assessment

First Application of Lognormal Distribution to Occupational Data

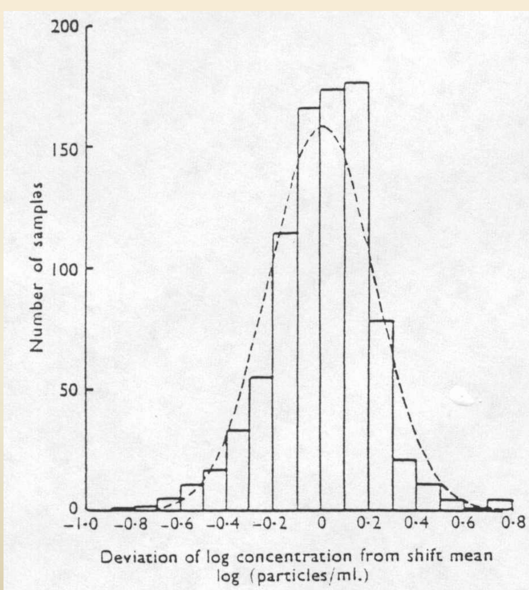

FIG. 2.—Distribution of deviations of 779 transformed samples from their shift means, with the Normal curve of equal area and standard deviation 0·2203.

Histogram of logged deviations of 779 breathing-zone measurements of dust in British coal mines [from Oldham (1953)].

Provides basis for advanced statistical modeling of data

Rappaport and Kupper (2008)
Quantitative Exposure Assessment 22

Exposure Data in Modern Epidemiological Studies

Only 13% of studies used quantitative measurements

Methods of exposure measurement 31

Table 2.2 Distribution of the main methods of exposure measurement (one selected from each study) in 564 studies of the aetiology of non-infectious disease published in the *American Journal of Epidemiology* between January 1980 and December 1989

Methods	Distribution (%)
Personal interview	49.1
Face to face	43.0
Telephone	4.1
Unclassifiable type	2.0
Self-administered questionnaire	14.0
By mail	6.4
Under supervision	7.6
Reference to records	22.3
Medical records	7.1
Other records	15.2
Physical or chemical measurements	13.3
On subject	10.8
On environment	2.5
Unclassifiable	1.2

From: B.K. Armstrong *et al. Principles of Exposure Measurement in Epidemiology*, Oxford Med. Pubs., 1992

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Sample Sizes for Workplace Measurements after OSH Act of 1970

- Many professionals (mostly employer-based)
- Advanced personal samplers and direct-reading monitors
- Focus upon hazard control rather than health surveillance
  - Only 16 new OSHA PELs since 1971
- Almost all air monitoring for acute hazards ('safety'), e.g., confined spaces, LEL, O_2 deficiency, substances IHTL
- Few measurements for chronic health effects
  - Median = 4 meas. from 696 published studies reviewed by Symanski *et al.* (1967-1996)

What about industrial surveys?

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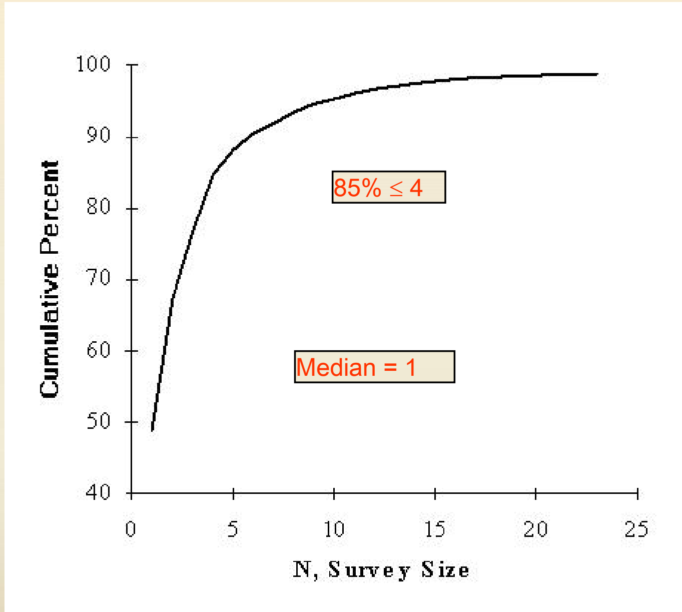
Sample Sizes for Industrial Surveys



Numbers of measurements obtained in 4864 annual surveys of occupational groups of workers in the nickel producing industry 1970 – 1990. [From (Tornero-Velez *et al.*, 1997)].

25

Better Equipment & More Professionals but Fewer Measurements – Why?

- Current trends
  - From government inspectors to employer-based inspectors (vested interests)
  - Increasing reliance on measurement–free methods (‘exposure models’, ‘control-banding’, etc.)
  - From exposure-response (long time frame) to *compliance* with OELs (short time frame)
- OELs have existed since the 1950s
  - Prior to 1970 OELs were guides
  - After OSH Act they became legal limits

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Compliance Testing

- Rarely performed by OSHA inspectors
  - Fewer than 10,000 health inspections per year in 2.5 million US workplaces (P{health inspection} < 0.004/year)
- Vast majority performed by employers who must provide workplaces "…free from recognized hazards."
  - Company representatives (e.g., IH) *can* measure personal levels of persons in all groups with potential for excessive exposures
- One-to-one comparison of observed air levels with PEL
  - Compliance: All measurements < PEL
    - No additional measurements needed

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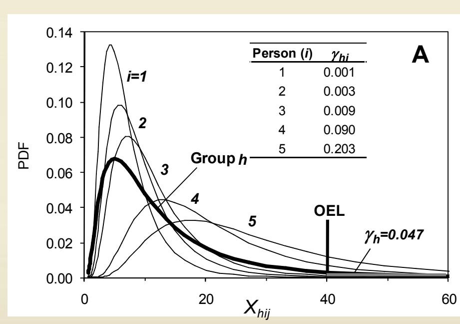
Probability of Compliance

- Let γ_h represent the probability that a person in Group *h* would be exposed on one day above the OEL (exceedance of Group *h*)
  - $\gamma_h = P\{X_{hij} > OEL\}$



- Then the probability of compliance for Group *h* is

$$P\{C_h\} = (1 - \gamma_h)^{N_h}$$

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

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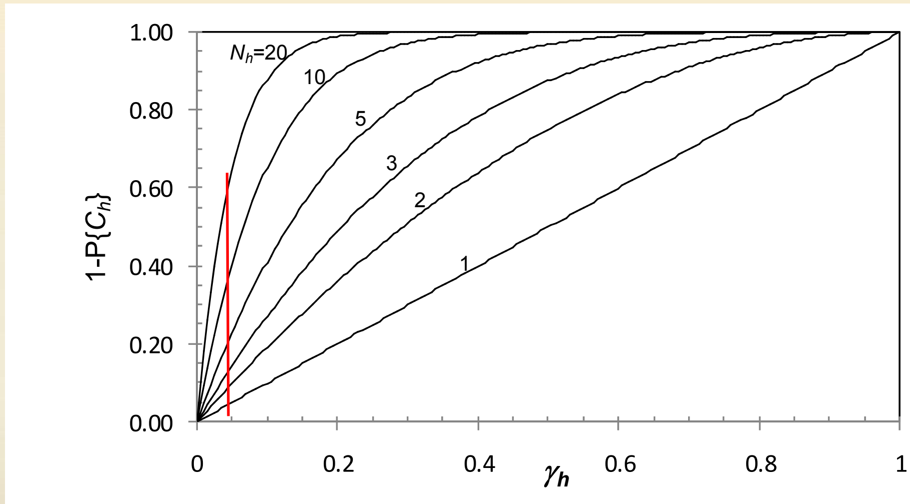
Noncompliance and Sample Size



Rappaport and Kupper (2008)
Quantitative Exposure Assessment

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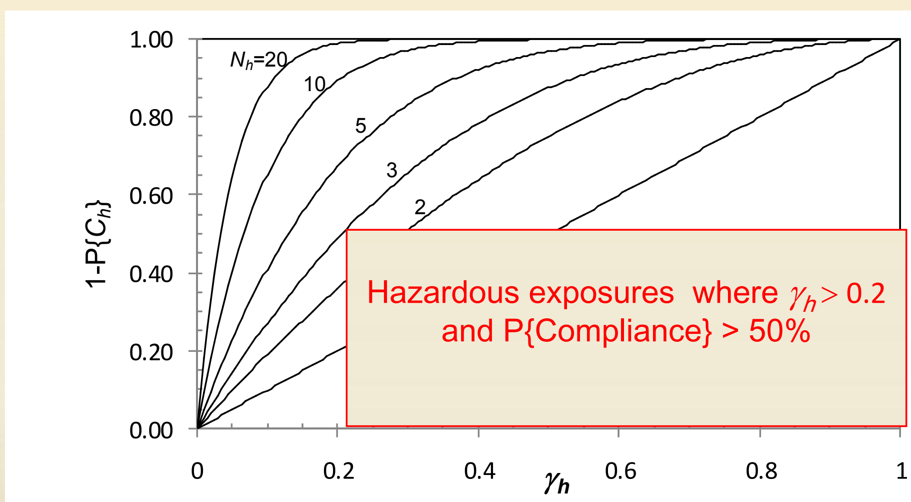
Noncompliance and Sample Size



Since P{C_h} depends greatly on N_h, employers have incentive to maximize P{C_h} by making very few measurements
(Compliance testing can only be applied with small sample sizes)

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

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The Advantage of Air Monitoring

- OSHA standards mandate air monitoring for conditions IHTL (safety standards)
- Employers have incentives to avoid situations IHTL (confined spaces, trigger alarms, etc.)
- – Acute hazards easily assessed (reduces employer liability)
- – Hundreds of direct-reading air monitors commercially available
- Employers prefer to measure *air levels* of chronic toxicants because they are not clearly tied to *exposures*
- – Use of area rather than personal measurements
- – Evaluating air levels for tasks rather than workers
- – Can ignore between-worker differences in exposure

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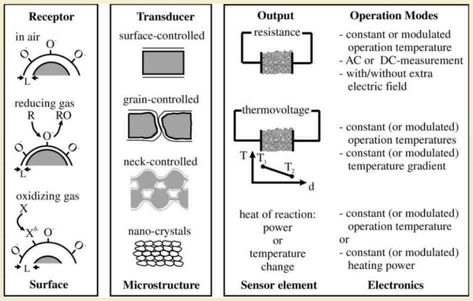
The Problem with Exposure Monitoring

- Under the OSH Act the burden of proof is upon the government to prove noncompliance with PELs
  - But there are essentially no government inspections (the OSH Act is based upon voluntary compliance!)
  - The use of compliance testing implicitly discourages *exposure* monitoring
- But - chronic health effects are slow to develop and difficult to relate to exposures without extensive exposure monitoring
  - Many employers don't want extensive exposure data in their files
- The situation is unlikely to change without a paradigm shift, such as REACH (**R**egistration, **E**valuation, **A**uthorization and Restriction of **C**hemical **H**azards) which places the burden of proof on the manufacturer to prove the safety of its products

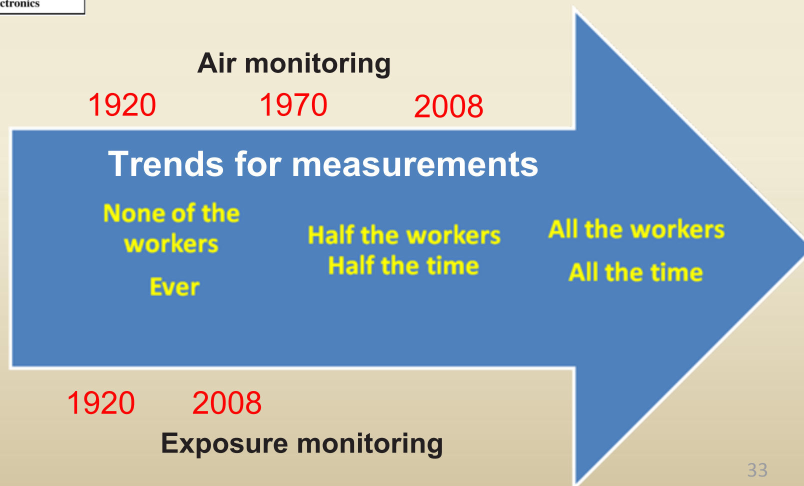
32

If you build it will they come? (You've got a DREAM …)



I. Simon et al. / Sensors and Actuators B 73 (2001) 1±26

Nanosensors of the future:
Ultra-small personal monitors
Multiple analytes
Data logging
Measure all workers' exposures – to everything - all the time!



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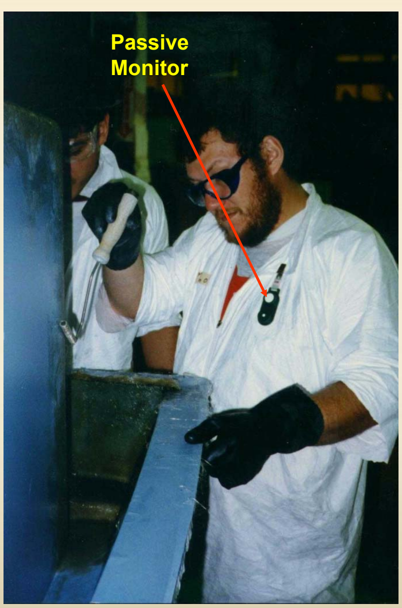
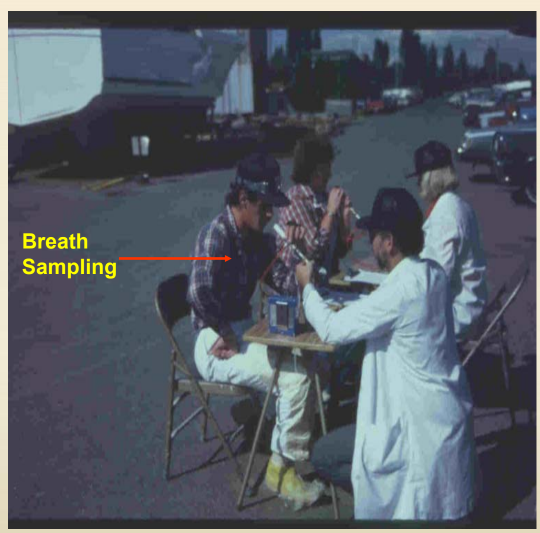
What about biomarkers of exposure?





Described in: Yager, et al. (1993) *Mut. Res.* 319:155-165.

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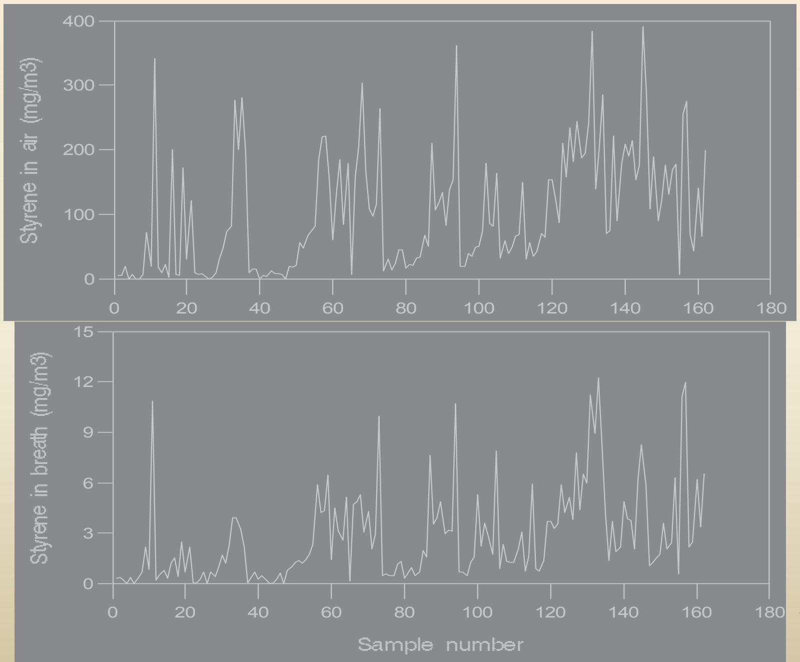
Styrene in Air and Breath

Reinforced-plastics workers (3 – 7 meas./subj.)

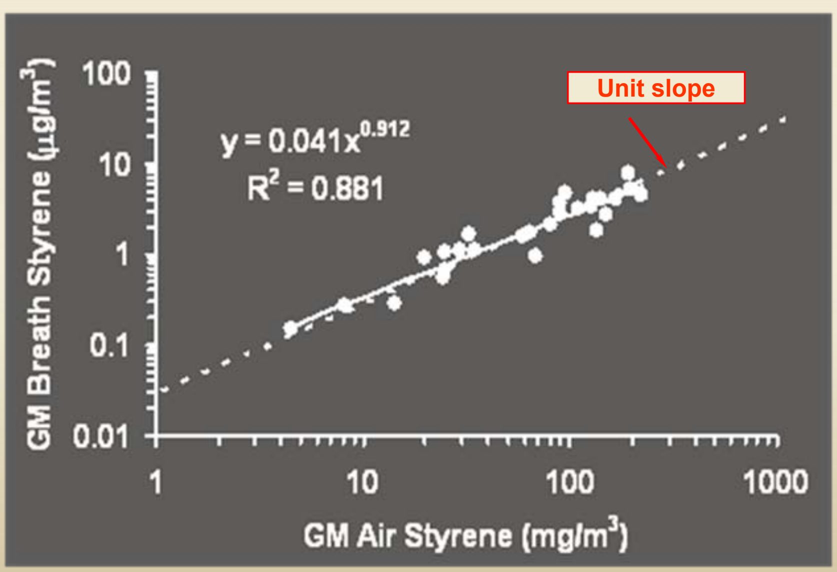


Data from: Rappaport, *et al. Cancer Res*, 56: 5410-5416 (1996)

35

Styrene in Air and Breath

Reinforced-plastics workers (3 – 7 meas./subj.)



Data from: Rappaport, *et al. Cancer Res*, 56: 5410-5416 (1996)

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DREAM Biomarkers of Exposure

- Good idea
  - Highly relevant to exposure and health effects
  - When used with exposure measurements can illuminate important human kinetic processes
  - Adaptable to nanosensing and LOC systems (high throughput, multiple analytes)
- But U.S. employers don't like biomarkers (even less than personal exposure measurements)
  - Few OSHA standards require biomonitoring (Pb, Cd)
  - More demand in Europe, Asia, and for non-occupational exposures in the U.S.

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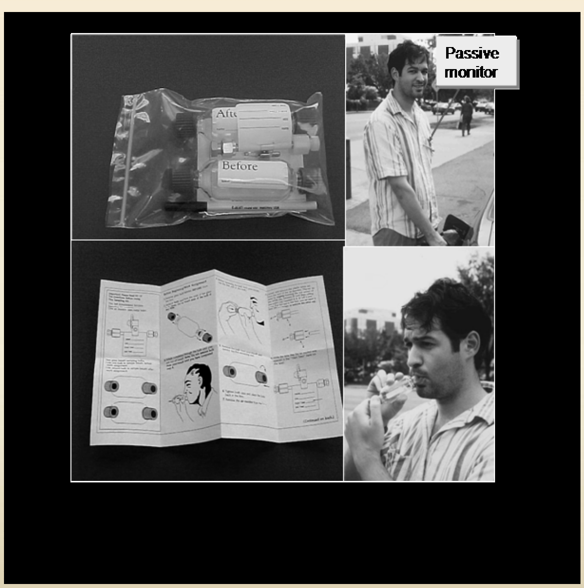
Self-Assessment of Exposure



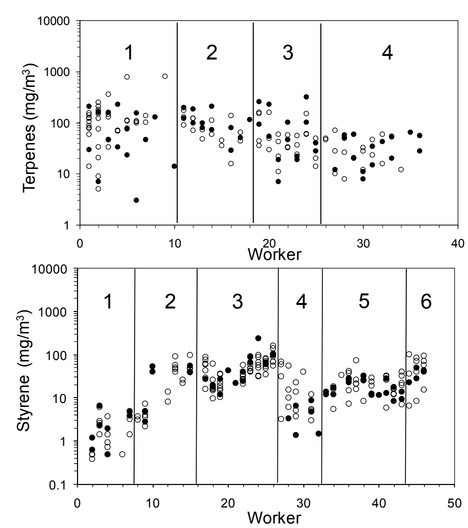


Fig. 3.2 Exposures to terpenes in sawmills (top) and to styrene in reinforced plastics factories (bottom). Open circles represent self-measurements made by workers and closed circles represent measurements made by an occupational hygienist on different days. Numbers represent different workplaces of a particular type. [Data from Liljelind *et al.* (2001)].

Rappaport and Kupper (2008)
Quantitative Exposure Assessment

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Take Home Messages

- Historically, exposure measurements were the holy grail that motivated breathing zone and personal sampling for studies of health effects
  - Early studies recognized exposure variability and included many measurements as a result

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Take Home Messages

- Hazard control trumps health surveillance for contaminant measurements in U.S. workplaces
  - Regulatory focus is upon acute (safety) hazards not health hazards
  - Only 16 new OSHA standards in 37 years
  - Emphasis upon compliance with PELs discourages employers from monitoring exposures
  - Reinvigorating exposure monitoring will require a paradigm shift (e.g., REACH-type system)

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Take Home Messages

- Exposure levels vary tremendously across groups, between workers (within groups), and within workers over time
  - Puts a premium on repeated exposure measurements over the long term
  - Sophisticated statistical models needed to characterize exposures and their determinants

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Take Home Messages

- Applications of DREAM technology for air (rather than personal) measurements are straightforward
  - Satisfy needs for control of acute hazards
- Extending DREAM to collect large numbers of measurements of personal exposure or biomarkers will require a shift in regulatory focus and/or enforcement

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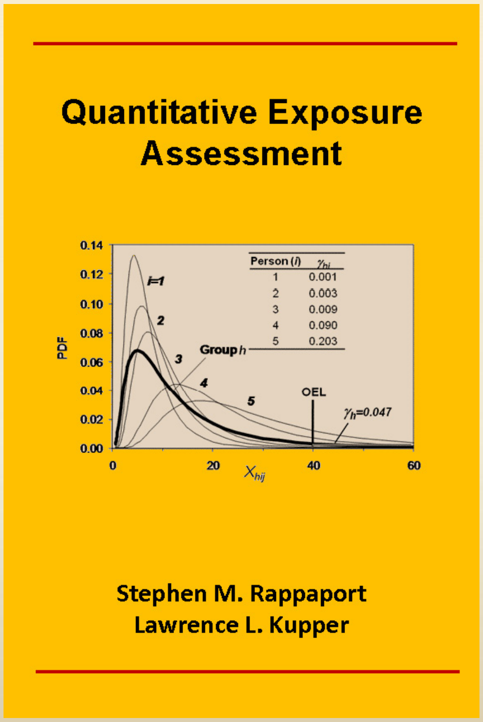
30 Years of thinking - in 183 pages



- The vagaries of exposure limits
- Measurement-based exposure assessment
- Statistical tools for exploring exposure variability
  - Within- and between-worker sources of variability
  - Determinants of exposure
- Implications for hazard control and epidemiology
- Choosing between environmental measurements and biomarkers

Available from Lulu Press
http://www.lulu.com/content/1341905

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Gas and Vapor

Direct-Reading Exposure Assessment Methods Workshop Agenda

Day 1 – November 13, 2008 Gas and Vapor

1:30 to 3:00 PM **Hazard-Based Presentations and full group discussion**

Jay Snyder *Dr. Ted Zellers* – Monitors
NIOSH Professor, University of Michigan
Jason Ham – Rapporteur
NIOSH

Presentations

Dean R. Lillquist, PhD
Director, OSHA Salt Lake Technical Center

- *History of OSHA's use of direct reading instruments, the Agency's current applications, and possible future directions.*

Mark Spence
Manager, North American Health and Safety Regulatory Affairs, Dow Chemical

- *Experiences and needs for direct reading methods and instrumentation from a broad chemical producer's perspective.*

Mark Spence
International Isocyanate Institute

- *Current direct readings instrumentation and anticipated future challenges and needs for the polyurethanes industry.*

Rebecca Blackmon, PhD
Technical Support Working Group

- Instrumentation for gas and vapor detection currently under development.

Ted Zellers, PhD
Professor of Environmental Health Science, U of Michigan

- Development of the micro gas chromatograph.

Jay Snyder
Sensor Project Officer, NIOSH

- Application of MEMs sensors currently under development to direct measurement instrumentation.

Direct Reading Instruments and OSHA

Dean R. Lillquist, PhD, CIH
Director, OSHA Salt Lake Technical Center

DREAM Workshop

11/08

OSHA Occupational Safety and Health Administration

Commercial manufactures and products mentioned in this presentation are for descriptive use only and do not constitute endorsements by USDOL-OSHA

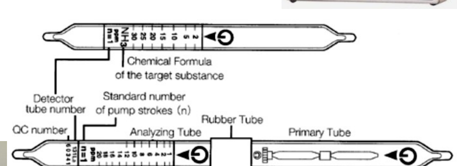
OSHA Occupational Safety and Health Administration

Historical use of direct reading instruments

- Noise dosimeters

- Heat Stress

- Colorimetric tubes



A closeup of Gastec gas detector tube(s)

- Ecolyzer

OSHA adds value to business, work and life

Direct reading instruments for permit required confined space entry

- **"permit-required confined space"**
  - describes a confined space that among other characteristics: contains or has the potential to contain a hazardous atmosphere.
- **1910.146(c)(5)(ii)(C)** Before an employee enters the space, the internal atmosphere shall be tested, with a calibrated direct-reading instrument, for oxygen content, for flammable gases and vapors, and for potential toxic air contaminants, in that order.
- **1910.146(c)(5)(ii)(F)** The atmosphere within the space shall be periodically tested as necessary …

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Types of Gases or Vapors OSHA wants to measure

- Oxygen
- Flammable
- Toxic - PELs

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Direct Reading Instruments for exposure monitoring - regulations

- 1910.1028, Benzene, Appendix D, Sampling and analytical methods for Benzene monitoring and measurement procedures
  - Sampling and analysis may also be performed by portable direct reading instruments, real-time continuous monitoring systems, passive dosimeters or other suitable methods. The employer has the obligation of selecting a monitoring method which meets the accuracy and precision requirements of the standard under his unique field conditions. The standard requires that the method of monitoring must have an accuracy, to a 95 percent confidence level, of not less than plus or minus 25 percent for concentrations of benzene greater than or equal to 0.5 ppm.

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OSHA Cincinnati Technical Center
Equipment Evaluation Considerations

- Check Manufacture Specifications
- Cost considerations
  - upfront and recurring
- Testing/Evaluation
  - Operational, Environmental, Electromagnetic Susceptibility
- Servicing and quality
- User friendliness

OSHA
adds value to business, work and life

OSHA Salt Lake Technical Center

- OSHA Salt Lake Technical Center is home to the Agency's :
  - Analytical Services
  - Sampling and Analytical Methods Development
- Regarding exposure assessment - integrated sampling with laboratory analysis has been the gold standard for OSHA

OSHA adds value to business, work and life

OSHA Salt Lake Technical Center

Integrated Sampling and Analytical Methods Development

Evaluation Guidelines For Air Sampling Methods Utilizing Chromatographic Analysis
47 pages

Evaluation Guidelines for Air Sampling Methods Utilizing Spectroscopic Analysis
39 pages

Target Concentrations
Reliable Quantitation Limit (RQL)
Reproducibility
Sampling Rate and Capacity
Extraction Efficiency

Detection Limit
Determination of the Precision
Interferences
Retention Efficiency
Effects of Storage

OSHA adds value to business, work and life

Written reports fall into three basic categories:

- ***Evaluated Methods*** - methodology that has been thoroughly evaluated according to the guidelines.
- ***Partially Evaluated Methods*** - procedures for which an in-depth evaluation has not been performed. Often performed rapidly to meet immediate need of field personnel.
- ***Studies*** - Investigations that involve a class or group of analytes, or an aspect of methodology that may be common to many methods in general. Unsuccessful evaluations will be reported as studies.

OSHA adds value to business, work and life

SLTC Direct reading methods

- **1993 - SLTC evaluated the Draeger 190 – CO monitor.**
- OSHA ID-209
  - CARBON MONOXIDE IN WORKPLACE ATMOSPHERES

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OSHA Salt Lake Technical Center

Portable Field Instruments

Evaluation Guidelines, with Testing and Reporting Protocols for OSHA On-site Air and Surface Sampling Methods

35 pages

Target Concentrations
Linearity of Response
Response time
Uncertainty (precision and bias)

Detection Limit
Interferences (water vapor)
Face velocity effects
Interferences

OSHA adds value to business, work and life

Future of Direct Reading Gas and Vapor Instruments

- Market forces (demand)
- OSHA's willinginess to support "Cite on Site"
- Screening versus Compliance
- Safety and Health Management Systems

OSHA adds value to business, work and life


OSHA
adds value to business,
work and life.


D.R.E.A.M.
WORKSHOP

Direct Reading Exposure Assessment Methods (DREAM): A Large Chemical Producer's Perspective

Mark W. Spence, CIH

Environment Health & Safety

The Dow Chemical Company

13 Nov 2008

Topics

- Current DREAM use in the chemical industry
- Considerations in current DREAM use
- Considerations for Future DREAM Development

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DREAM – Chemical Industry Perspective

Current DREAM Use

- Most common use: confined space clearance / entry
  - LEL / Oxygen assessment
    - » most important
    - » Requires simple, rugged, reliable instruments workers can operate
    - » Many good instruments currently available
  - Chemical assessment
    - » Often single gas / vapor
    - » “Go / no go” clearance indicator
    - » Common techniques:
      - “length of stain” tubes
      - Photoionization detectors
      - Lab analysis if no acceptable DREAM

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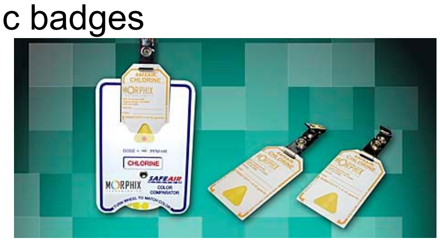
DREAM – Chemical Industry Perspective

Current DREAM Use (con’t)

- Industrial Hygiene Uses
  - Field exposure screening
  - Exposure contribution assessment
  - Task procedure improvement
  - Common methods
    - » Photoionization (PID)
    - » Flame Ionization (FID)
    - » Infrared (IR)
    - » Portable GC-(PID, FID, MS, ECD,…)
    - » Colorimetric badges



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Considerations in Current DREAM Use

- Method Selection involves balance of many factors:
  - Detection limit vs. range
  - Specificity vs. broad applicability
    - » Single component monitoring?
    - » Single component with a mixture present?
    - » Multiple component monitoring?
  - Initial cost vs. long-term value
    - » Leveraging use of costly instrument
      - IH & fugitive emissions
      - Centralized loan service
    - » Cost of consumables, repairs, calibrations
  - Worker-performed sampling vs. trained instrument operator
  - Datalogging vs. visually read in the field
  - Portable vs. "luggable"

Considerations in Current DREAM Use (con't)

- Accuracy more important than precision
  - Most IH decisions are "single significant digit"
- Most common problem in IH DREAM use: insufficient consideration of use environment
  - Other detectable species present
  - Effects of humidity, temperature, dust
  - Sufficient / relevant calibration
- DREAM may be a substitute when IH lab services not available or extremely expensive (not uncommon outside US)
- DREAM sometimes crucial for medical treatment decisions (e.g., phosgene badge)

Considerations for Future DREAM Development

- Improved analyte specificity
  - » Compound libraries, “fingerprinting” schemes
  - » Automated rather than user-dependant
- Applications for more VOCs (ethylene, acrylonitrile, ethylene oxide; all that have a TLV®?)
- Error / fault checking and notification
- Environmental compensation (e.g., humidity, temperature correction)
- Datalogging with ready export to common software (e.g., Excel)
- Easily worn by worker
- Improved value / cost of ownership
  - » Multiple applications
  - » Reliability
  - » Consumables cost & shelf life

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D.R.E.A.M.
WORKSHOP

Direct Reading Exposure Assessment Methods for Isocyanates: Current Options and Future Needs

Mark W. Spence, CIH
The Dow Chemical Company

13 Nov 2008

Topics

- Why are direct-reading exposure assessment methods (DREAM) useful for MDI & TDI?
- Current DREAM options for diisocyanates
- Future needs in DREAM for diisocyanates

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Why are DREAM Useful for MDI & TDI?

DREAM for Isocyanates

What are Isocyanates?

- "Isocyanates" refers to compounds containing the isocyanate functional group (-NCO).
- Commonly, the term is used to describe commercially important diisocyanate monomers used in the production of various polyurethanes.
- Toluene diisocyanate (TDI) and diphenylmethane diisocyanate (MDI) are the diisocyanates that Dow sells to customers who make polyurethane products:
  - Flexible foams (e.g., bedding and seat cushions)
  - Rigid foams (e.g., insulation)
  - Elastomers and coatings (e.g., footwear & automotive components)

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Why DREAM for MDI & TDI?

- Primary effect of inhalation over-exposure: respiratory sensitization and occupational asthma
  - Evidence supports 20 ppb ceiling / STEL as protective for prevention of respiratory sensitization
  - Toxicology suggests avoidance of brief high peak exposures important

➔ Rapid, in-field indication of such situations for workers is important

Current DREAM Options for MDI & TDI

Current DREAM Options for MDI & TDI

- Demands on DREAMs for MDI & TDI
  - Low (ppb) Exposure Guidelines
  - Reactive species (+/-)
  - Aerosol vs. vapor (MDI)

Current DREAM Options for MDI & TDI (con't)

- *Colorimetric Methods*
  - Reaction with colorimetric reagent coated on paper tape, plastic film substrate
  - Orange / red color develops; read by visual color comparator or photodiode
  - Pro:
    - » Fairly sensitive (1 ppb) and specific
    - » Cost reasonable
  - Con:
    - » Some cross-sensitivities (e.g., NOx)
    - » Doesn't differentiate between different isocyanates
    - » Responds to color density; dirt, high humidity will register
    - » Shelf life limited – refrigerated storage required

Colorimetric DREAM Devices

- Instruments –
  - Air pumped through paper tape (reel)
  - Hand-held or stationary
  - Numerical display, alarms & datalogging
  - 30 sec to 4-min sampling time

Colorimetric DREAM Devices

- Dosimeter Badges –
  - Diffusive sampling using paper / polymer patch
  - Qualitative / semi-quantitative (comparator)
  - 15 min exposure needed to read 20 ppb

DREAM for Isocyanates

Current DREAM Options for MDI & TDI (con't)

- *Non-colorimetric Methods:* IMS (Ion Mobility Spectrometry)
  - Ni^{63} ionization, TOF-type MS detection
  - Pro:
    - » Sensitive and specific
    - » Rapid response
    - » Compact
  - Con:
    - » Expensive
    - » Ni^{63} Source may pose travel problems
    - » Little industry experience with it yet

13 Nov 2008

DREAM for Isocyanates

Future DREAM Needs for MDI & TDI

13 Nov 2008

Future DREAM Needs for MDI & TDI

- ***Key need:*** Exposure Profiling
    - Short-term peak measurements
        - » Smallest time increment possible
        - » High sensitivity
        - » Rapid recovery
    - Data-logging
    - Compatible with video exposure assessment
        - » Time stamp
        - » Software for easy synchronization
    - Easily worn by worker

Future DREAM Needs for MDI & TDI (con't)

- Sensitivity & Specificity
    - 0.1 ppb to accomodate possible lower OELs
    - Differentiate TDI, MDI from other isocyanate-containing species (e.g., aliphatic isocyanates (HDI, IPDI), oligomers, methyl isocyanate, isocyanic acid)
    - Accurate readings of isocyanate-containing aerosols
    - Absence of environmental effects (dust, humidity, NOx interference)
    - Accuracy +/- 25% min

Future DREAM Needs for MDI & TDI (con't)

- Device requirements
  - Lightweight (< 3 lbs [1.4 kg])
  - Worker-wearable without interference in tasks
  - Battery powered (minimum 8-hr run time)
  - User-adjustable alarm points (including no alarm option)
  - Flexible, user-friendly data download software compatible with standard software (e.g., Excel)
  - UL-approved, intrinsically safe
  - Consumables shelf-life > 6 months
  - "Reasonable" cost

Hurdles for New DREAM Development

- Market size vs. development cost
  - DREAM very useful to isocyanate and polyurethane producers
  - Technical demands for isocyanate DREAM high
  - Market small compared to other more general DREAM uses
- How the isocyanate industry can help:
  - Laboratory evaluation of new devices
  - Field evaluation of new devices


D.R.E.A.M.
WORKSHOP

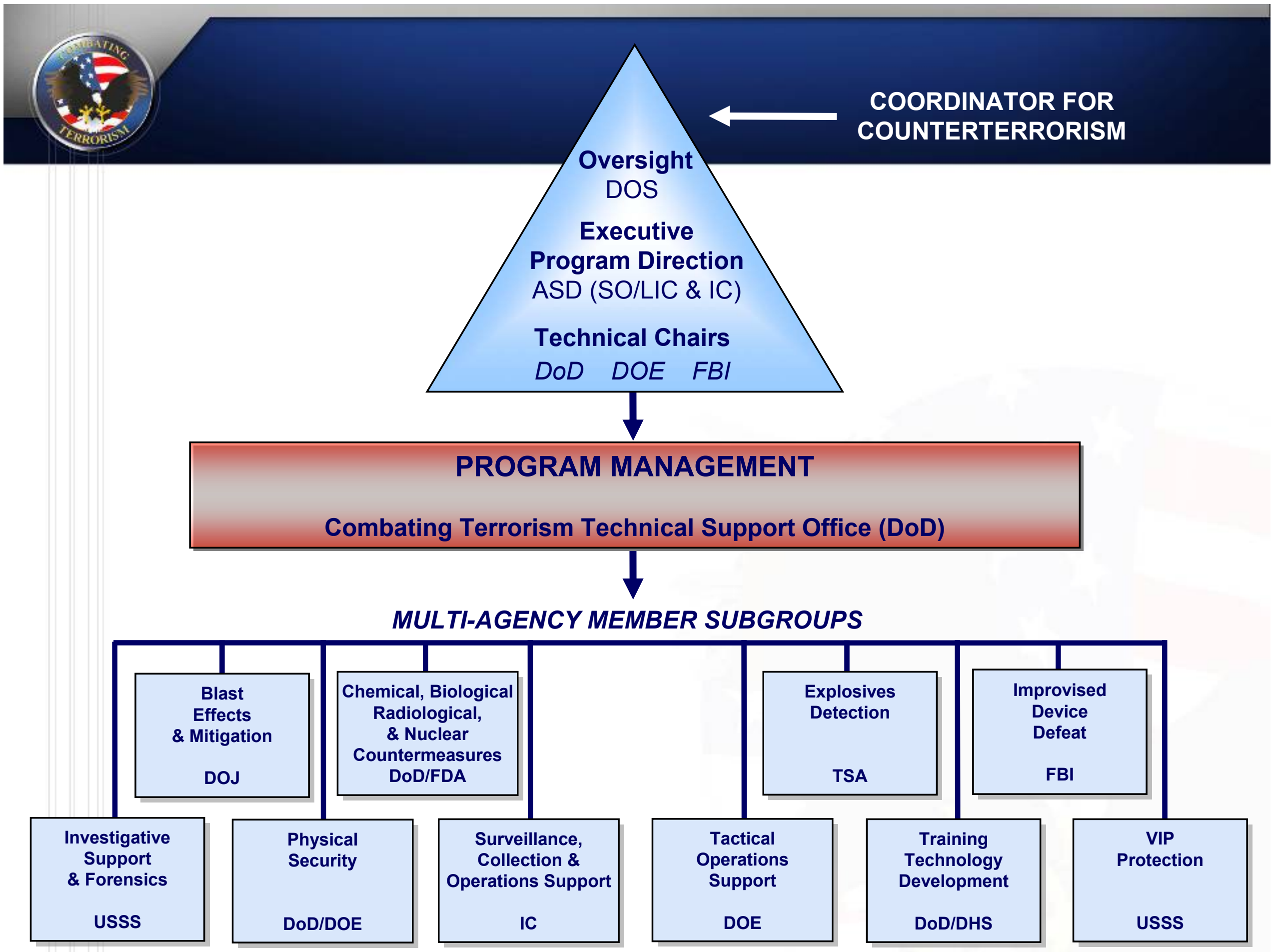
CTTSO
Combating Terrorism Technology Support Office

Chemical, Biological, Radiological, and Nuclear Countermeasures

NIOSH DREAM Workshop
13 Nov. 2008
Dr. Rebecca Blackmon
CBRNC Subgroup

TSWG Mission

- **Mission:** Conduct the U.S. national interagency research and development program for Combating Terrorism through rapid research, development, and prototyping.
- **Objectives:**
  – Provide interagency forum to coordinate R&D requirements for combating terrorism
  – Sponsor R&D not addressed by individual agencies
  – Promote information transfer

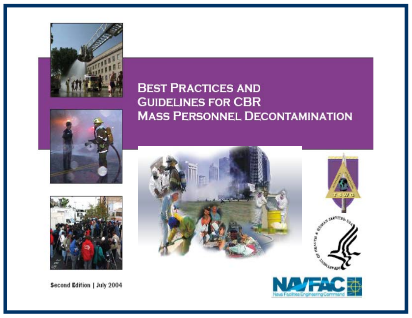


CBRNC Subgroup Mission

- Identify interagency user requirements related to terrorist-employed chemical, biological, radiological, and nuclear (CBRN) materials
- Rapid research, development, and prototyping
- **Objectives:**
  - Provide interagency forum to coordinate R&D requirements for combating terrorism.
  - Sponsor R&D not addressed by individual agencies.
  - Promote information transfer.
  - Influence basic and applied research.

CBRNC Focus Areas

Information Resources



Detection

Consequence Management

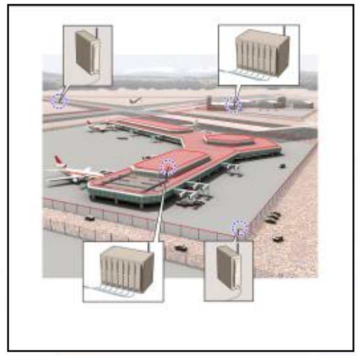
Protection

ChemSight^{TM} TIC and CWA Warning Monitor

Open-path IR sensor capable of detecting airborne chemicals. Can be installed indoors or along outdoor perimeters.

Developer: Avir Sensors, LLC
<http://www.avirsensors.com/>

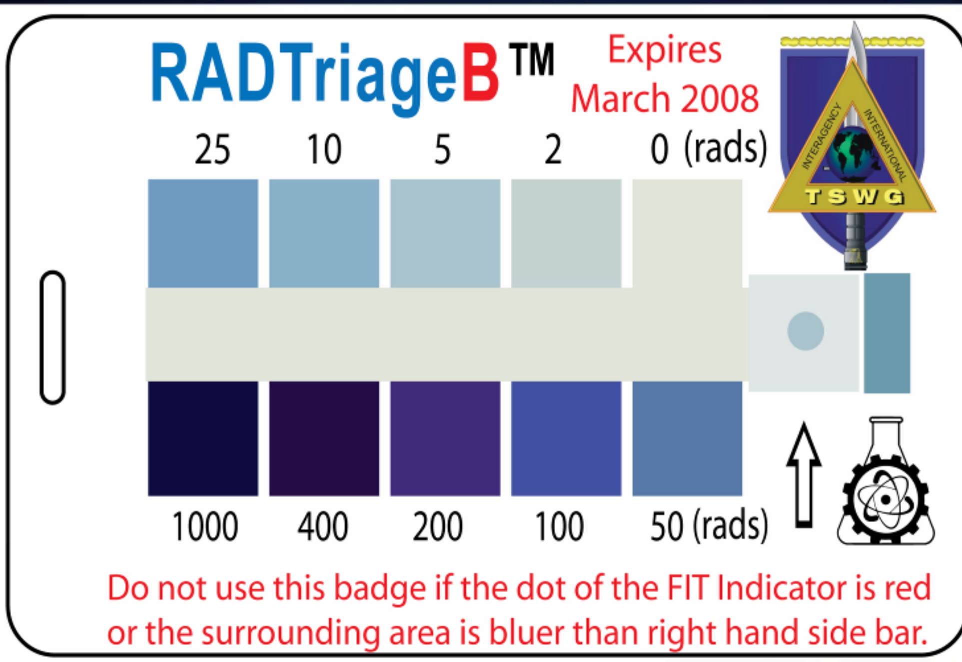
Distributed Chemical Sensor (DICAST©)



Monitor large areas, such as buildings and installation perimeters for chemical warfare agents and toxic industrial chemicals.

Developer: Intelligent Optical Systems, Inc. <http://www.intopsys.com/index.html>

Radiation Detection/Triage for Decon



Developer: JP Laboratories, Inc.
<http://www.sirad-usa.com/html/radtriage.html>

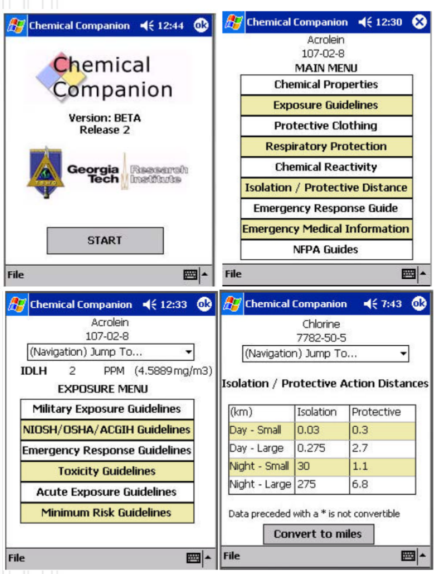
Ocular Scanner

Portable and automated triage tool for non-invasive assessment of exposure.

- Assess exposure in five seconds or less.
- Detects changes in visible light spectrum of arterial and venous blood and iris response.

Developer: EyeMarker Systems, Inc. <http://eyemarker.com/>

Chemical Companion



An emergency response tool that provides incident-site hazard analysis.

- Exposure guidelines for chemicals
- Identifies suitable PPE
- Establishes failure/breakthrough times of filters & PPE
- Rapidly assesses stay time vs. risk to personnel

Developer: Georgia Tech Research Institute; info at: <http://www.chemicalcompanion.org>

Summary

- Forum to identify, prioritize, resolve, and fund operational needs/requirements
- Driven by interagency user elements
- Acquisition/dual-use/commercialization

Contact Information

CBRNC Subgroup
cbrncsubgroup@tswg.gov

http://www.tswg.gov

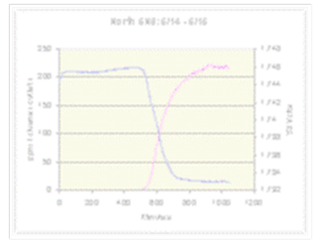

D.R.E.A.M.
WORKSHOP

National Personal Protective Technology Laboratory

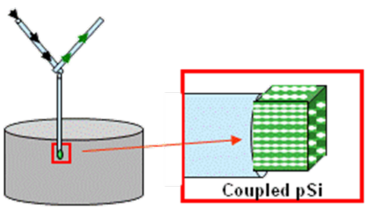
Sensor Development for ESLI

&

Application to Chemical Detection

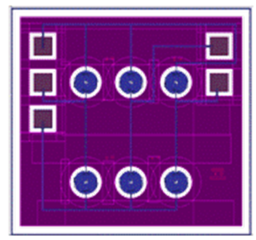


Jay Snyder- NIOSH



412-386-6775

JSnyder@cdc.gov



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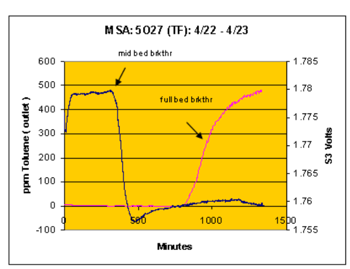
Presentation Outline

- Current and Future Electronic System Work
- Current and Future Optical System Work



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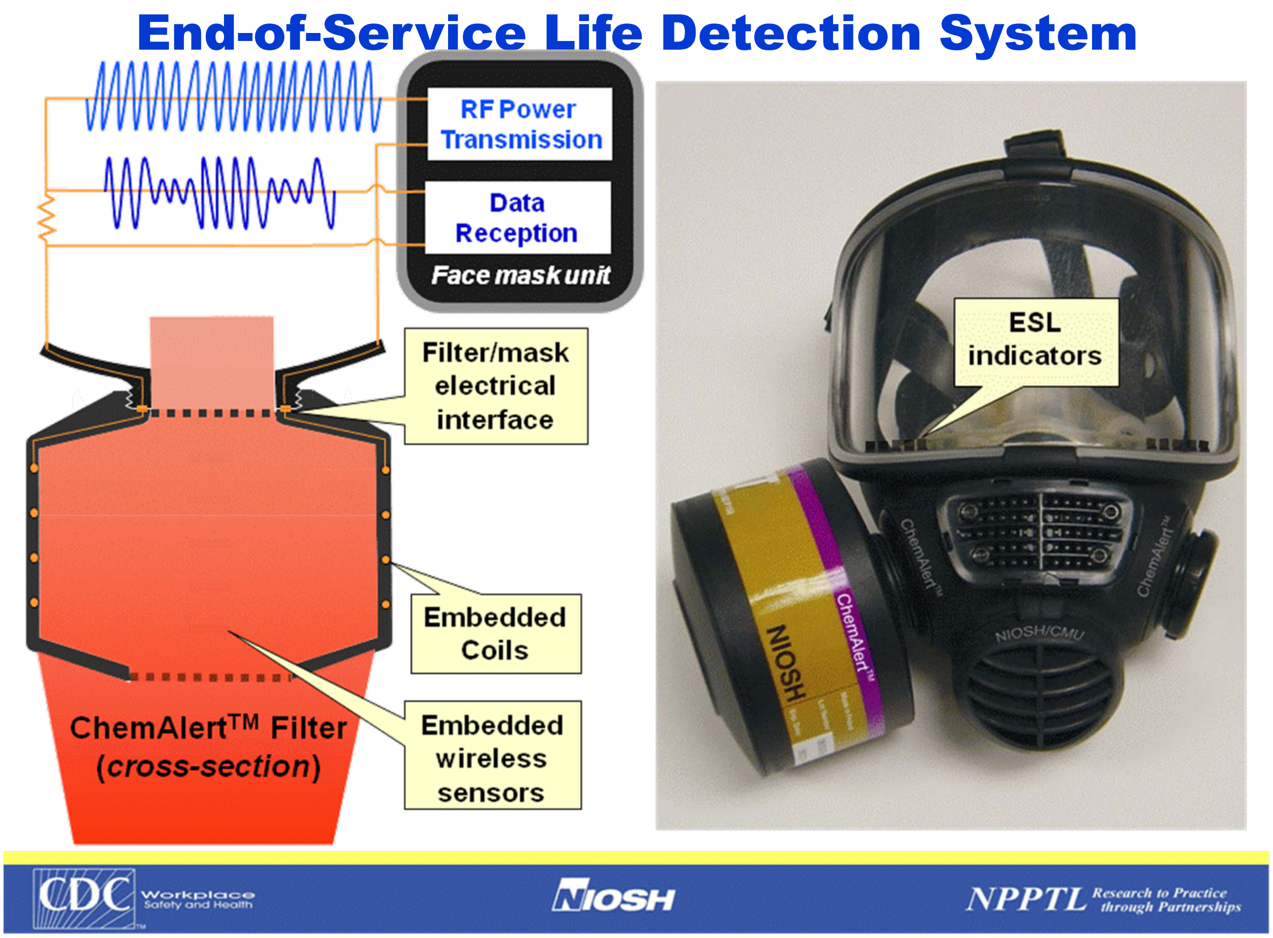
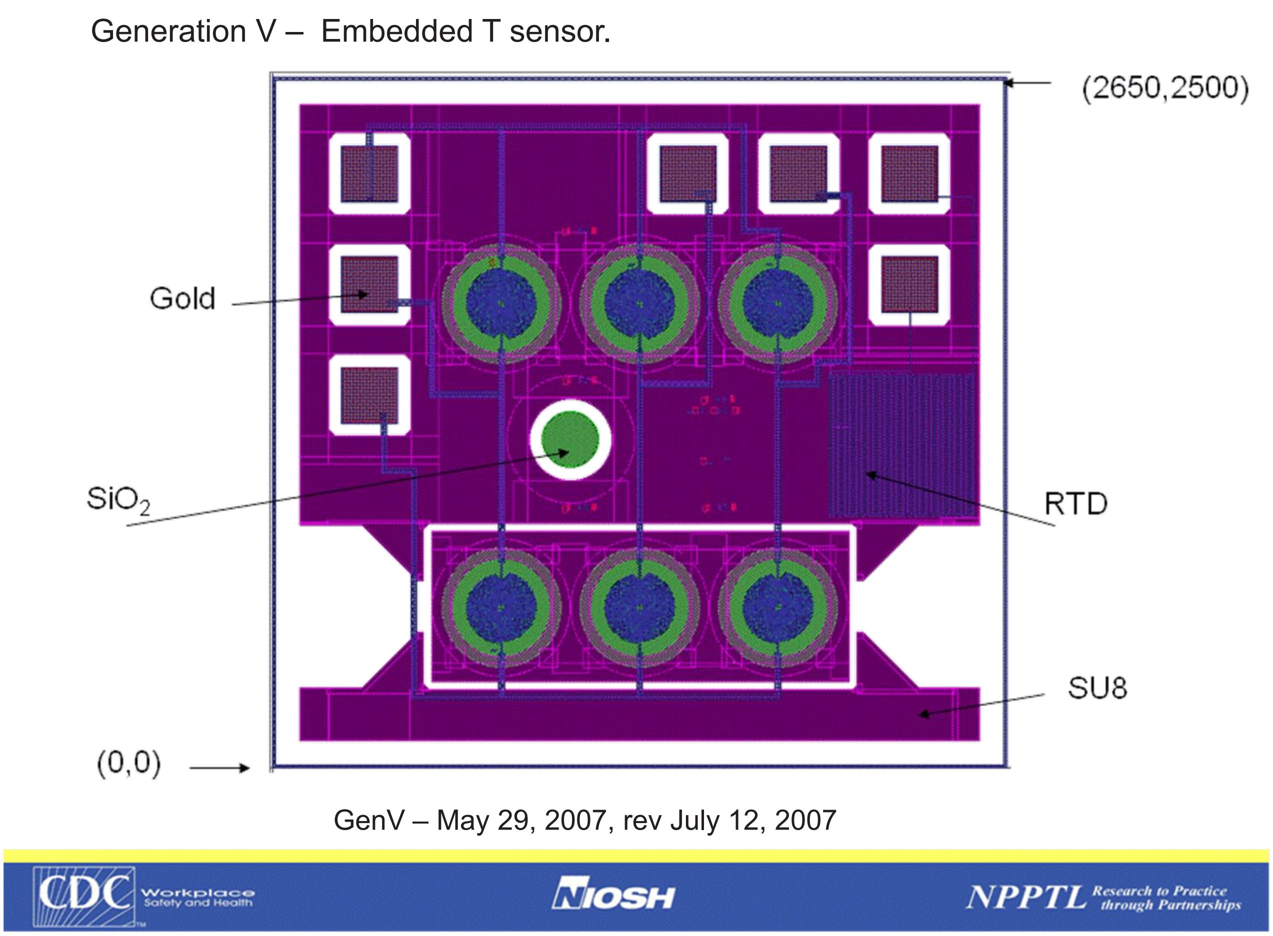

End-of-Service Life Detection System
RF Power Transmission
Data Reception
Face mask unit
Filter/mask electrical interface
Embedded Coils
Embedded wireless sensors
ChemAlert™ Filter (cross-section)
ESL indicators
NIOSH
ChemAlert™
NIOSH/CMU
CDC Workplace Safety and Health
NIOSH
NPPTL Research to Practice through Partnerships


Generation V – Embedded T sensor.
(2650,2500)
Gold
SiO2
RTD
SU8
(0,0)
GenV – May 29, 2007, rev July 12, 2007
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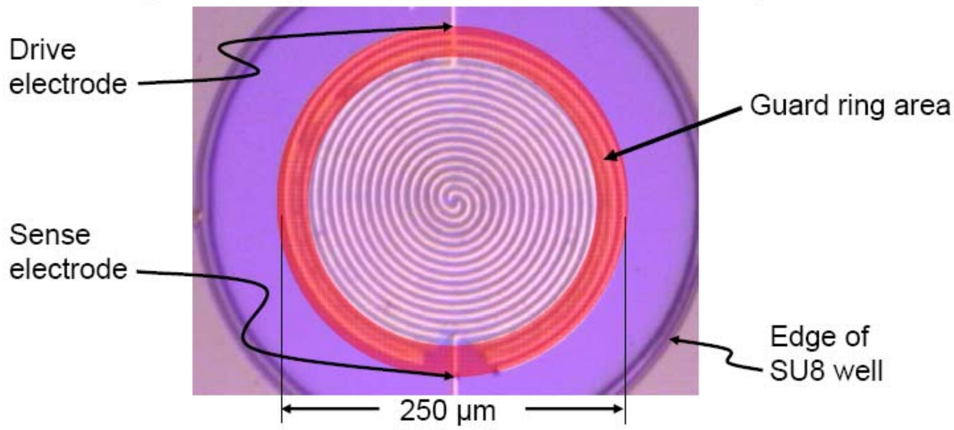
Electrode Design

- **Spiral interdigitated gold electrodes**
  - Symmetric coverage of jetted splat
  - 3 µm-wide traces, 4 µm spacing, 75 nm thick
- **Sized to accommodate 30 to 60 µm diameter nozzles**
- **Outer guard ring to achieve better uniformity**



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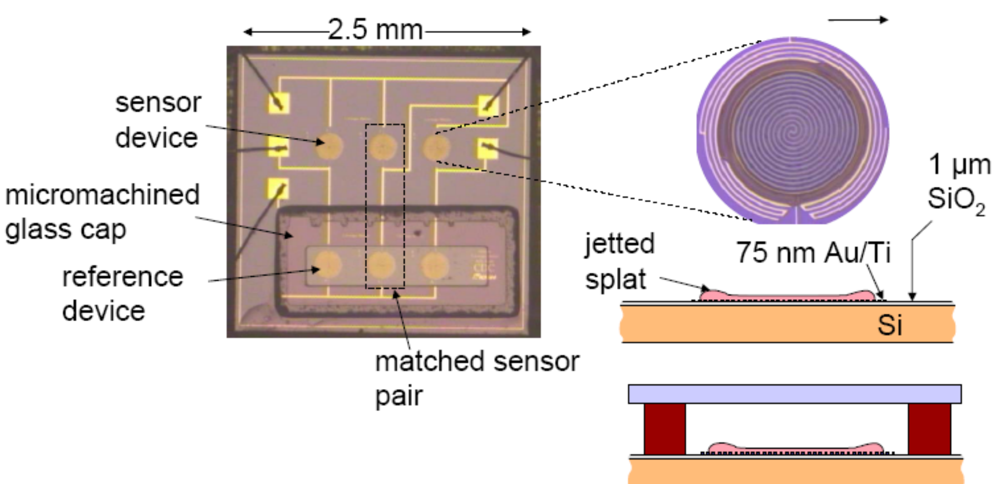
Sensor Circuit Chip

- **3 chemiresistive sensor circuits**
- **Reference devices capped with glass/SU8 epoxy cap**
- **Sealed with low outgassing arathane**



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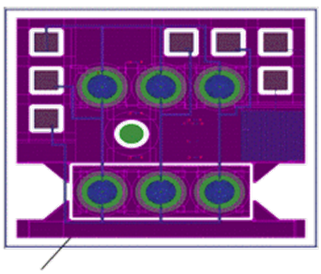
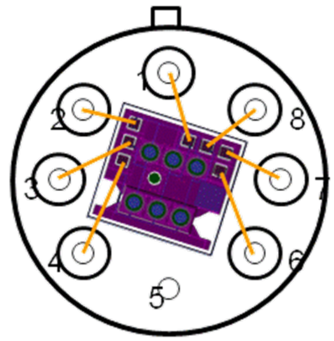
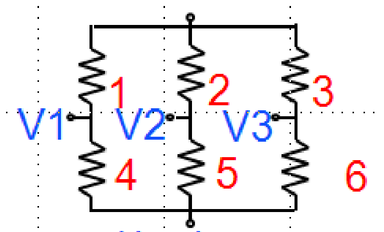
Sensor Assembly



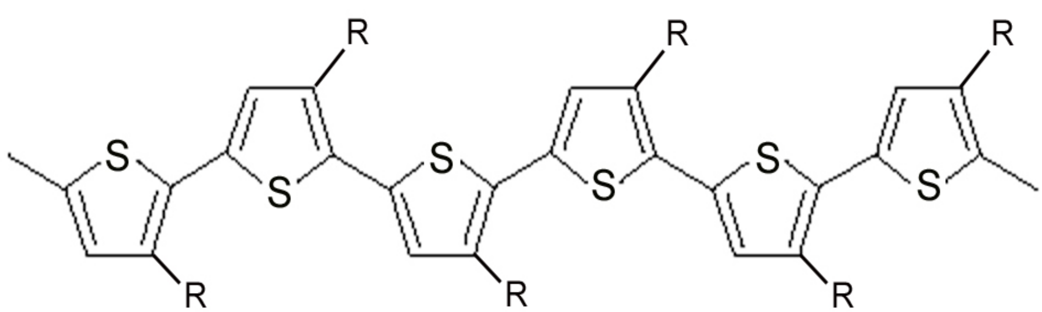


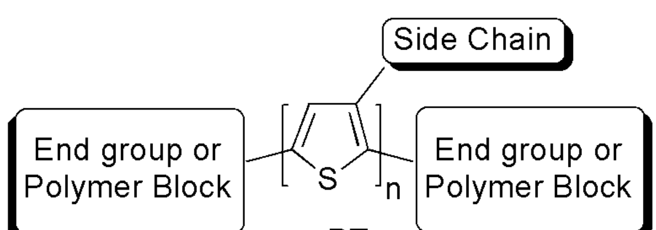
Sensor



TO-5

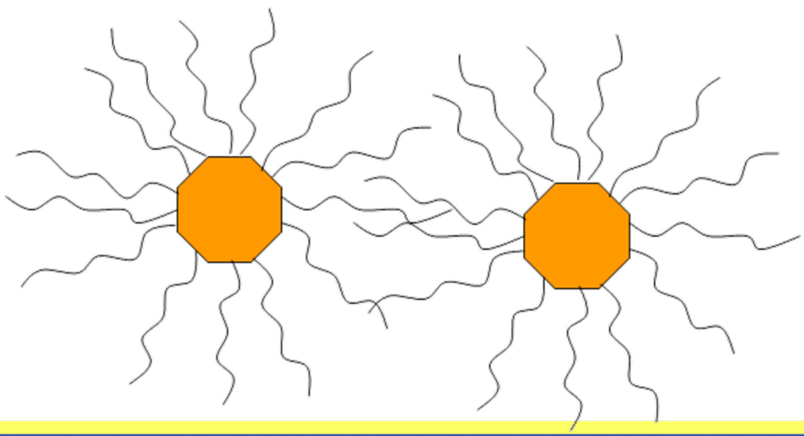
Regioregular poly(alkylthiophene)





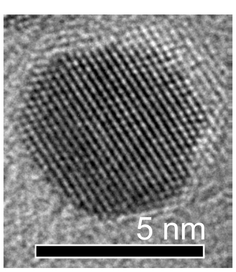
What are Au-Monolayer Protected Clusters?

- **Composite material consisting of a cluster of gold atoms surrounded by a single layer of an organic molecule (thiol) bound to the metal through a sulfur atom:**

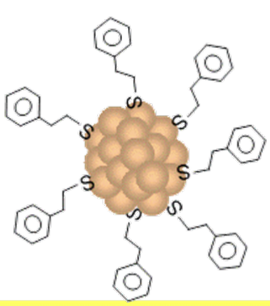


Nanoparticle Terminology

Nanoparticle:
• Solids in a size range of 1-100 nm in diameter (a general term).
• New phenomena not seen in atoms/molecules or bulk will emerge at this scale (**The exact size at which this happens depends both on the system and the property being considered*).



Nanocrystal: single crystalline nanoparticles (typically > 2nm to exhibit crystallinity (i.e. translational symmetry).



Nanocluster or cluster: individual molecular units that have **well-defined** structure (e.g. Au_{11} and Au_{25}), but are too small to be true crystals, with sizes ranging from subnanometer to ~2 nm).
They are closely akin to molecules in terms of transport and other properties.

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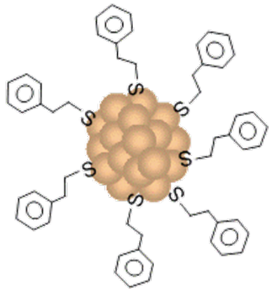
Gold Nanoclusters for VOC sensing



A New Type of Ultrasmall Gold Nanoparticles:

- These particles have well-defined composition and structure (e.g. Au_n, n=the # of gold atoms);
- Too small to be true crystals (size ranging from subnanometer to 2 nm);
- New physiochemical properties that could benefit VOC sensing.

Synthetic Challenges:

1. How to achieve the ultrasmall size (< 2nm)?

— Ultrasmall size effects electron quantum confinement (semiconducting gold nanoparticles)

2. How to achieve atomic monodispersity?

— Controlling the # of atoms in a particle via kinetic control (atomically monodisperse: the ultimate)

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MPC Properties

- **Easy to handle**
  - Air stable.
  - Soluble in organic solvents*.
  - Can be coated on substrates by ink-jetting, dipping, spinning and spraying.
- **Can be modified**
  - Size and shape.
  - Functional end groups of organic monolayer.
  - *Solubility determined by the nature of the monolayer.
- **Reusable**

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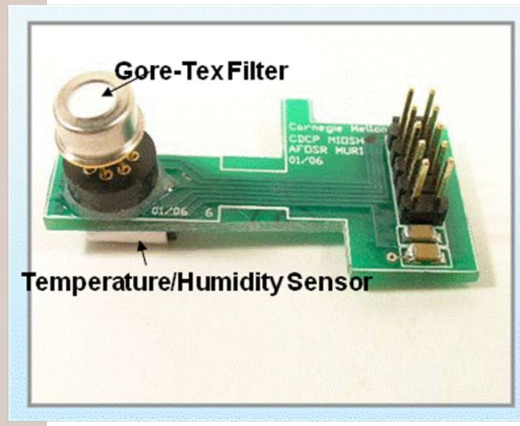
Complete TO-5 Package



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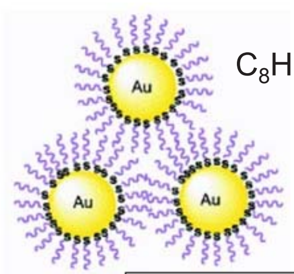
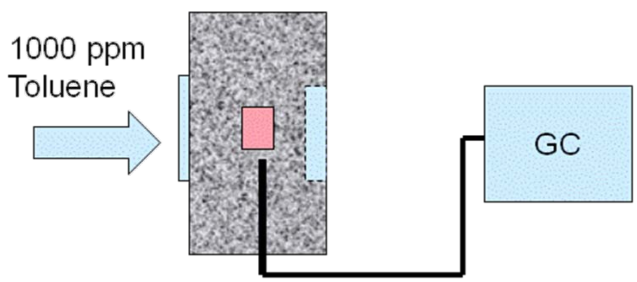
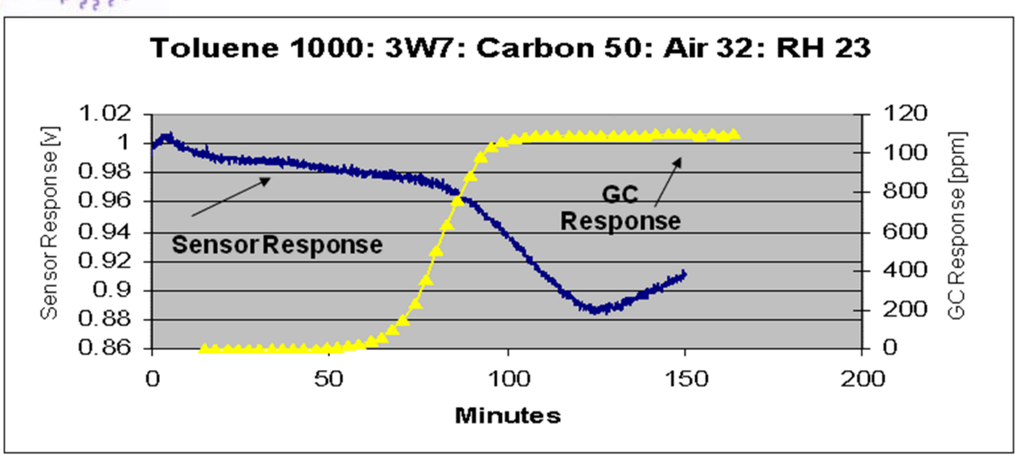
Performance of a MPC



$C_8H_{17}SH$
(C8)





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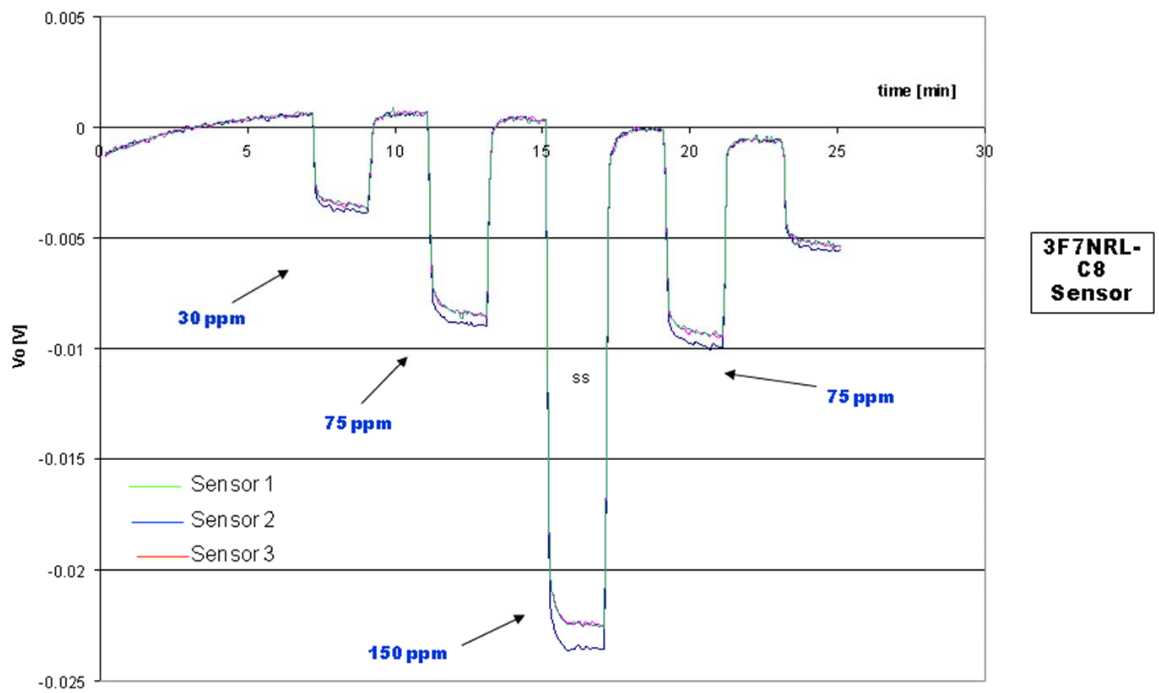
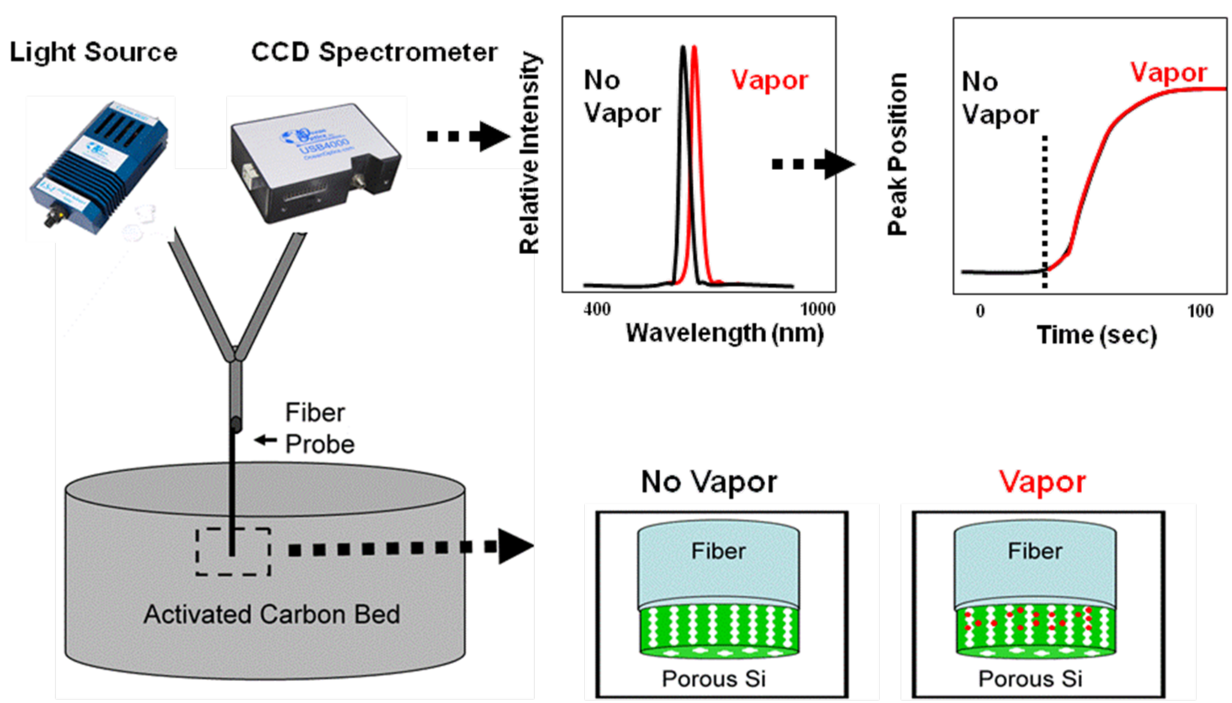
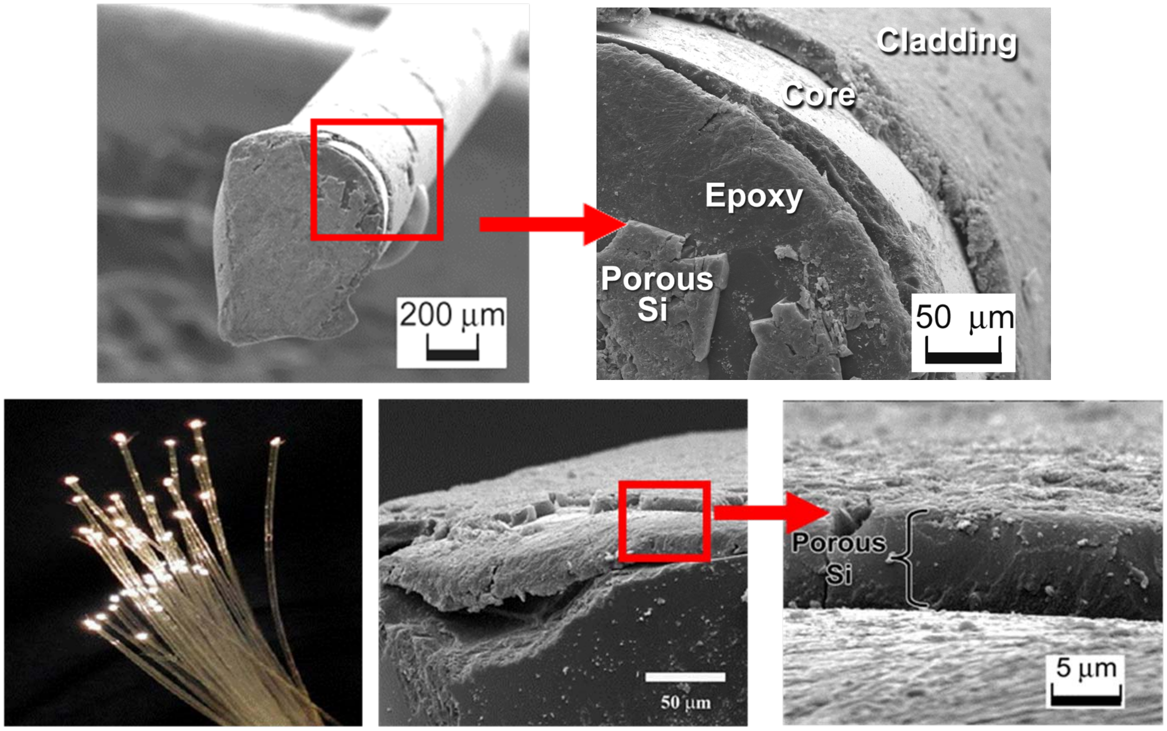
MPC Sensor Response to Toluene in Air



Optical Fiber Sensing Scheme



Attachment to Optical Fiber



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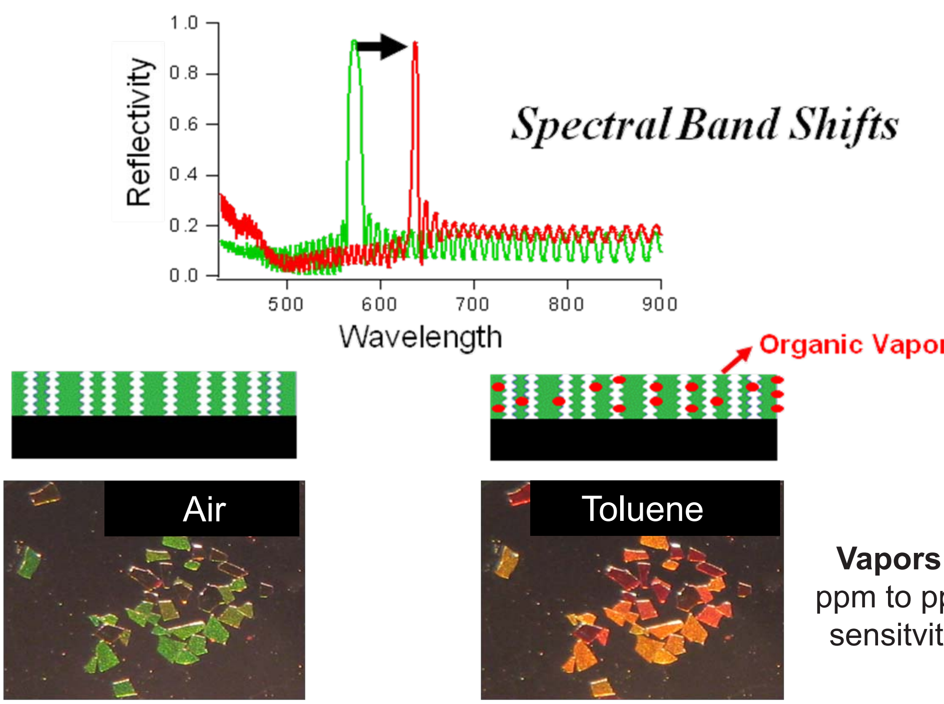
General Sensing Scheme



Vapors:
ppm to ppb
sensitvity

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Conclusions

- NIOSH and its partners have made great progress toward ESLI for organic vapor respirator cartridges.
- Prototype electronic sensor systems have been inserted into commercially available cartridges.
- Optical based ESLI systems have completed proof of concept testing.

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Summary

- Many ESLI design parameters still need to be optimization and continued development is underway.
- Application to commercial chemical detection is possible.

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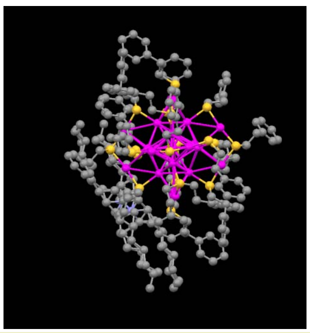
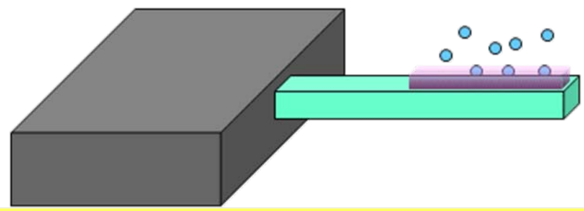
Disclaimer:

The findings and conclusions in this presentation have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.



Thank you



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Aerosols

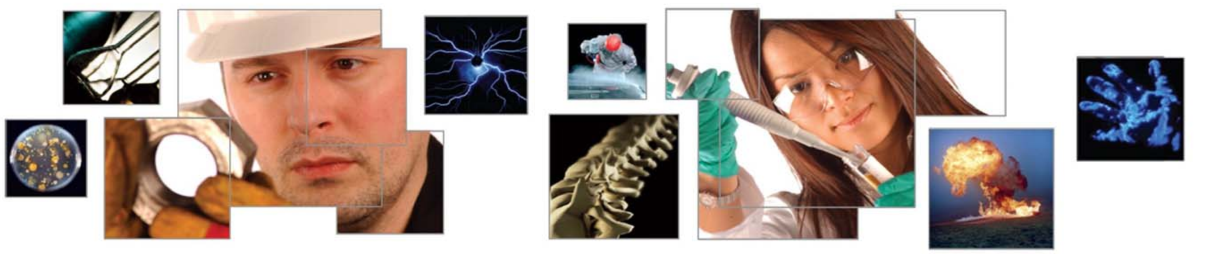
Day 1 – continued Aerosols

Session 2: Aerosols
Monitors: Martin Harper (NIOSH), Pam Susi (CPWR)
Speaker/Title of Presentation:
1. David Mark (Health & Safety Laboratory, UK) - European standard for direct-reading aerosol instruments
2. Jon Volkwein (NIOSH) - The development of a personal dust monitor for coal mines
3. Peter Görner (INRS, France) - Evaluating concentration of aerosol particles in occupational hygiene using optical particle counters
4. Mike Brisson (SRS) - Real-time needs for beryllium particle detection
5. Pam Susi (CWPR)/John Meeker (U of Michigan) – To be determined
6. James Noll (NIOSH) – Reducing exposures to diesel particulate matter (DPM) using direct-reading instruments

Rapporteur: Terri Pearce (NIOSH)
Topics of discussion:
1. Characterization
2. Sizing of particles
3. Validation
4. Calibration
5. Specific NIOSH National Occupational Research Agenda (NORA) sector needs

CEN Draft Technical Report ‘Guide for the use of direct-reading instruments for aerosol monitoring’

Dave Mark
Member of CEN/TC137/WG3



www.hsl.gov.uk
An Agency of the Health and Safety Executive

CEN/TC137/WG3

- European standards committee:
  ‘Assessment of Workplace Exposure – Particulate Matter’.
- Produces standards and technical reports (guidelines) on measurement of exposure to aerosols in the workplace
- Currently working on standards for:
  - Revision of EN 13205: Assessment of performance of instruments for measurement of airborne particle concentrations
  - prEN ISO 28439: Characterisation of ultrafine aerosols/nanoaerosols – Determining the size distribution and number concentrations using differential electrical mobility analysing systems
  - Revision of EN 15051: Measurement of the dustiness of bulk materials – requirements and test methods
  - CEN/TR: Guide for the use of direct-reading instruments for aerosol monitoring

CEN/TC137/WG3 (cont'd)

- Strong liaison with:
  - ISO/TC146/SC2/WG1, Air Quality/Workplace Atmospheres - Particle Size-selective Sampling and Analysis (hold joint meetings – David Bartley ex-NIOSH, convenor)
  - ISO/TC44/SC9/WG2, Health and Safety in Welding and Allied Processes – Sampling of airborne particles and gases in the operator's breathing zone
  - ISO/TC229, Nanotechnology – WG2: Measurement and Characterisation, WG3: Health, Safety and Environment

CEN/TRxxxx: Guide for the use of direct reading instruments for aerosol monitoring

Currently has three parts:

Part 1: Choice of monitor for specific applications
Draft 5 – I will present here

Part 2: Evaluating airborne particle concentrations using Optical Particle Counters
Draft 4 – Peter Görner will present here

Part 3: Evaluating airborne particle concentrations using Photometers
Not yet started

Part 4: Evaluating airborne particle concentrations using other devices
May not be started – depends on availability and use of suitable instruments (TEOM, piezobalance, β attenuation, etc)

Part 1: Choice of monitor for specific applications

Contents of Part 1

2. Scope and area of application

- Aim of Part 1 of TR is to produce *simple, easy-to-read* document to enable *non-specialists* to choose most appropriate monitor for their job
- The *principles* underlying the evaluation of one or more aerosol fractions using direct-reading aerosol monitors are given
- Involves only *currently available* methods for monitoring levels of aerosols in workplaces for a range of different purposes
- Details of their *limits and possibilities* in the field of occupational hygiene are given
- Does *not cover* the sampling of aerosols for compliance with occupational exposure limits or the collection of aerosol particles for subsequent analysis
- Does *not include* instruments for ultrafine and nanoparticles (they will have separate documents)

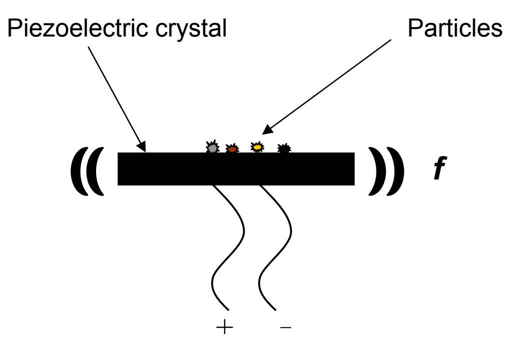
4. Principles of direct-reading aerosol monitoring methods

- Automatic methods are classified into three main groups:
  - Vibrational mass monitors
  - Beta attenuation monitors
  - Optical monitors
- Methods in first two groups involve sampling and collection of particles on substrates for analysis of mass by on-board techniques
- Optical monitors are the most numerous because of their high sensitivity and ease of use

Information given for each group

- For each group of monitors, the following information is given:
  - Operating principle
  - Determination of mass concentration of health-related fractions
  - Calibration of monitor
  - Advantages and disadvantages
  - Currently available monitors (not comprehensive)

Example: Piezoelectric mass monitors



Schematic of piezoelectric mass monitor

- Operating principle
  - Particles drawn into the instrument are collected the surface of a piezoelectric crystal, forming part of a quartz crystal-based oscillating circuit
  - The mass of deposited particles causes a reduction in the oscillation frequency *f*.
  - Frequency reduction is directly proportional to the particle mass

Aerosol concentration, $C = \dfrac{\Delta f}{Qtk_f}$

Δf = reduction in frequency

Q = sampling flowrate

t = sampling time

k_f = proportionality constant

Determination of mass concentration of health-related fractions

- Change in frequency Δf ❝ *mass* of particles deposited and largely *independent* of the physical and chemical properties of the particles
- No need therefore to use on site calibration factors, providing that the crystal is not overloaded
- Only *respirable* fraction is measurable, because of particle size limitations on particle/sensor coupling
- Respirable size selection can be achieved using any suitable size selector; one instrument uses a single stage impactor with the respirable particles deposited on the crystal by electrostatic precipitation.

Calibration of piezoelectric instruments

- Each crystal sensor has its own frequency response and so the instrument incorporating the crystal will be calibrated in the factory to give the required mass response.
- Provided that the crystal is not damaged, no further calibration is required.

Advantages/disadvantages of piezoelectric instruments

HEALTH & SAFETY LABORATORY

Advantages	Disadvantages
❖ Direct measurement of dust mass	❖ Usage limited by dust loading on crystal
❖ No on-site calibration required	❖ Regular cleaning of crystal required
❖ Response independent of chemical composition and particle size (below 10 μm)	❖ Only suitable for respirable particles
❖ Relatively easy to use	❖ Moisture can condense onto deposited particles and effect mass measurement

Currently available piezobalance instruments (manufacturer's information)

HEALTH & SAFETY LABORATORY

Name	Portable/ personal	Size (mm) /weight	Size selection	Flowrate ($l\ min^{-1}$)	Response time	Accuracy	Measurement range ($mg\ m^{-3}$)
Kanomax Piezobalance dust monitor Model 3511	Portable	311x170x130 2 kg	Respirable fraction by impactor	1	*0 – 1 mg m^{-3}*: 24 s *1 – 10 mg m^{-3}*: 120 s	± 10 % of reading	0.02 – 10

NOTE: "Accuracy" is defined by the manufacturers

Advantages/disadvantages of photometers

Advantages	**Disadvantages**
❖ Very fast response	❖ Response not directly proportional to mass, but is dependent upon particle size, shape and refractive index
❖ Very wide concentration range	❖ Need factory and on-site calibration for mixed or varying aerosols
❖ Portable and personal models available	❖ Response drops off for particles > 10 μm, so only suitable for respirable fraction
❖ Passive models require very little power	❖ Oversensitive to fine aerosols (e.g. water mist, fume and cigarette smoke)
❖ Pumped models may have filter collection that can be used for analysis	
❖ Very simple use (most simple of all types of monitor described)	

Currently available photometers (not comprehensive, manufacturers information)

Instrument name	Pumped (flowrate l min^{-1}), passive	Personal or portable	Size (mm) and weight (kg)	Particle size range (μm)	Measurement range (mg m^{-3})	Precision (mg m^{-3})	Accuracy	Resolution	Calibration	Display and data logging
Casella Microdust Pro	Passive	Portable	245x95x50 Probe 290x35ø 1.0	NM	0 - 2500	NM	NM	0.001 mg m^{-3}	Factory calibrated to ISO 12103-1 using A2 fine test dust and can be calibrated on-site using add-on pump/filter system	128x64 pixel screen gives rolling averages of concentration, 15,700 points data logger
SKC Haz-dust 1	Passive	Portable	229 x 70 x 63 0.5	0.1 - 50	0.01 - 200	± 0.02	± 10% to NIOSH 0600	NM	Factory calibrated to NIOSH 0600 with SAE fine dust	1 line LCD, Optional data logger
SKC Split2	Pumped (2) or passive	Personal	180 x 80 x 45 0.8	0.1 – 10 (R) 0.1 – 50 (T)* 0.1 – 100 (I)*	0.01 – 200	± 0.02	± 10% to NIOSH 0600	NM	Factory calibrated to NIOSH 0600 with ARD. Has inhalable entry and back up filter as standard and calibration post for on site	4 line LCD, 21,500 points data logger
TSI Sidepak	Pumped (0.7 - 1.8)	Personal	130x92x70 0.5	0.1 – 10 Built-in impactors to choose "none", 1.0, 2.5 or 10	0.001 – 20	NM	NM	0.001 mg m^{-3} (min)	Factory calibrated to respirable fraction of ISO 12103-1 with A1 test dust	2 line LCD, 31,000 points data logger
TSI Dustrak	Pumped (1.4 - 2.4)	Portable	221x150x87 1.5	0.1 – 10 (approx)	0.001 – 100	NM	NM	0.1% of reading or 0.001 mg m^{-3}	Factory calibrated to ISO 12103-1 with A1 test dust	1 line LCD, 31,000 points data logger
Thermo DataRAM 4	Pumped (1 to 3	Portable	134x184x346 5.3	0.08 - 10	0.0001 – 400	± 0.01	± 2% of reading ± precision	0.1% of reading or 0.0001 mg m^{-3}	Factory calibrated with SAE fine test dust and has in-built optical scattering element	8 line LCD, 50,000 points data logger
Thermo personal DataRAM	Passive or pumped (1 – 5) with add-on pump/filter system	Personal	153x92x63 0.5 (passive)	0.1 – 10 (max response)	0.001 – 400	± 0.005	± 5% of reading ± precision	0.1% of reading or 0.001 mg m^{-3}	Factory calibrated with SAE fine test dust and can be calibrated on-site using add-on pump/filter system	2 line LCD, 13,000 points data logger
Sibata PDS 2	Pumped (2)	Personal	Sensor 100x36x95 0.3 Control unit 98x43x106 0.5	NM	0.001 - 100	NM	± 10% to Calibrated latex particles	0.001 mg m^{-3}	Factory calibrated with 0.6 μm latex spheres	1 line LCD, 60,000 points data logger
Hund TM-μP	Passive	Portable	200x110x40 1.0	Respirable	0 - 100	0.01 (LOD)	NM		Factory calibrated with respirable coal dust –can be calibrated with other dusts	4 digit display in mass concentration
TSI Respicon	Pumped (3 – 11)	Personal	Sensor 110x63x69 0.48 Datalogger 210x100x55 0.58	Three fractions via virtual impactors	0-250 for each of the 3 stages	0.05 (LOD)	?30% following EN 13205 procedures	0.01 %		

NOTE: "Precision", "accuracy" and "resolution" are defined by the manufacturers themselves and may be different

NM = Not mentioned

5. Requirements for different applications of direct-reading aerosol monitors

- Presented here are the requirements that a suitable direct reading aerosol monitor must have for different applications.
- The reader can then compare these requirements with the characteristics of the available instruments given in Section 4 to enable the *most suitable choice* of direct reading aerosol monitor to be made for his/her *specific application*.
- Six different potential uses of direct reading aerosol monitors are discussed:
  - *Walk through surveys*
  - *Identification of main process or source emitting aerosols*
  - *Use with video visual techniques*
  - *Assessing efficiency of control systems*
  - *Watchdogs to monitor levels in workplaces and ensure controls are working*
  - *Surrogate personal exposure assessment*

Example 1 : *Walk through surveys*

- For walk through surveys, the direct-reading aerosol monitor should have the following attributes:
  - *Portable (battery-powered)*
  - *Response preferably independent of particle characteristics (particle size and composition)*
  - *Fast response time*
  - *Concentration displayed on an in-built screen*
  - *Particle size selection not important*
- Walk through surveys could provide additional information for inclusion in the Basic Survey outlined in EN 689 (1995) –Sampling strategy document

Example 2: *Watchdogs to ensure controls are working*

HEALTH & SAFETY LABORATORY

- For use as watchdogs to monitor levels in workplaces to ensure that deployed controls are working, the direct-reading aerosol monitor should have the following attributes:
  - *Simple, cheap (passive) monitors for multiple use around workplaces*
  - *Can be battery or mains powered*
  - *Response calibrated against reference monitors, possibly personal monitors for specific processes, so response does not have to be independent of particle characteristics*
  - *Information tele-metered to central hub system*
  - *Alarm function set to go off when agreed level exceeded*
  - *Fast response not necessary*

Example 3: Surrogate personal exposure assessment

HEALTH & SAFETY LABORATORY

- Direct reading aerosol monitors cannot currently be used to measure exposure to determine compliance with occupational exposure limits (OELs).
- However, there are a number of situations where an indication of exposure is important:
  - a) use with video visual techniques to demonstrate changes in techniques to minimise exposure for worker training,
  - b) for situations where there is no OEL and relative changes in exposure as measured with direct reading aerosol monitors can be used to demonstrate improvements in control.
- For this purpose, the direct reading aerosol monitor should have the following attributes:

Example 3: Surrogate personal exposure assessment - attributes

- *Personal and unobtrusive*
- *Particle size selectivity related to the potential health effects from the process being monitored*
- *Response calibrated on-site against in-built filter or suitable compliance sampler worn alongside direct reading aerosol monitor*
- *Fast response time for video visual work, but not necessary for demonstrating overall reduction in exposure*

Progress with guidance documents

- Currently Parts 1 and 2 have been accepted as new work items by CEN/TC 137
- Both have been under discussion for about 2 years, but still not final versions
- Any comments you may have will be very welcome!
- TIMELINE:

1 March 2009:	Circulation of first draft
1 September 2009:	Dispatch of draft for Technical Committee approval


D.R.E.A.M.
WORKSHOP

The development of a personal dust monitor for coal mines

Direct Reading Exposure Assessment Methods Workshop

Washington, DC
November 13, 2008

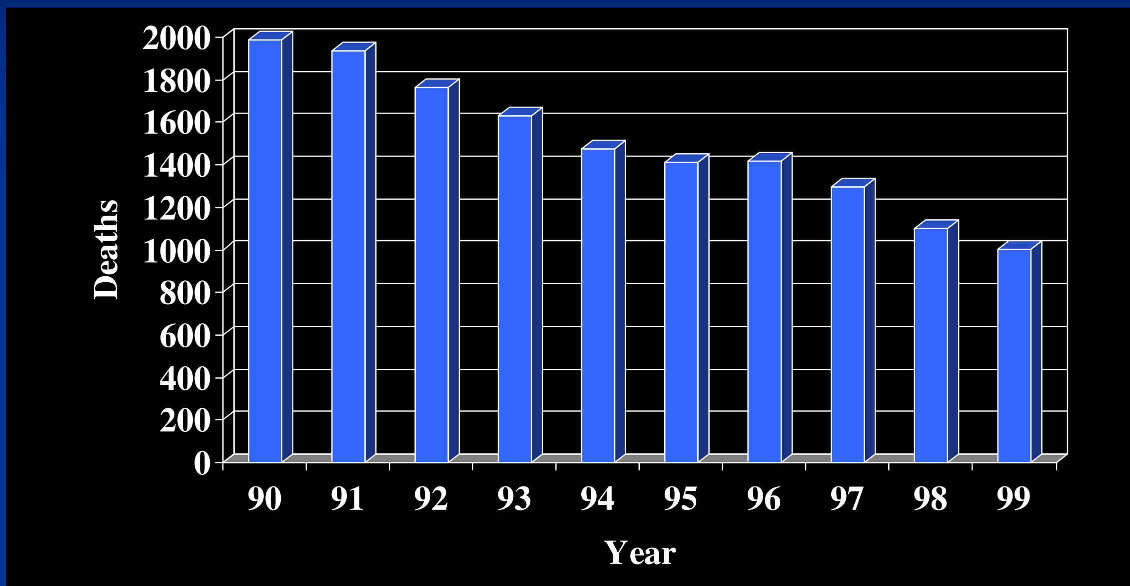
Outline

- Spoke on the worker aspects this am
- This talk focuses of the thought process of how to compare direct reading personal aerosol monitors with TWA
- Approaches to assess personal aerosol direct reading monitors
  - Laboratory
  - Field

CDC

NIOSH

Number of Deaths Attributed to Coal Workers' Pneumoconiosis



U. S. Coal Mine Dust Sampling

Little has changed in the last 30 years.

CDC

NIOSH

Direct Reading Exposure Assessment Needs

- Under recommendation of Secretary of Labor and the 1995 Federal Advisory Committee on the Elimination of Pneumoconiosis among Coal Mine Workers, NIOSH mandated to improve personal dust monitoring instruments to provide timely data output to miners
- U. S. miners interested in better technology for coal mine dust sampling for the past 20 - 30 years
- In consultation with labor, industry, and government, NIOSH contracted with R&P for the development of new mass based monitoring technology for mining

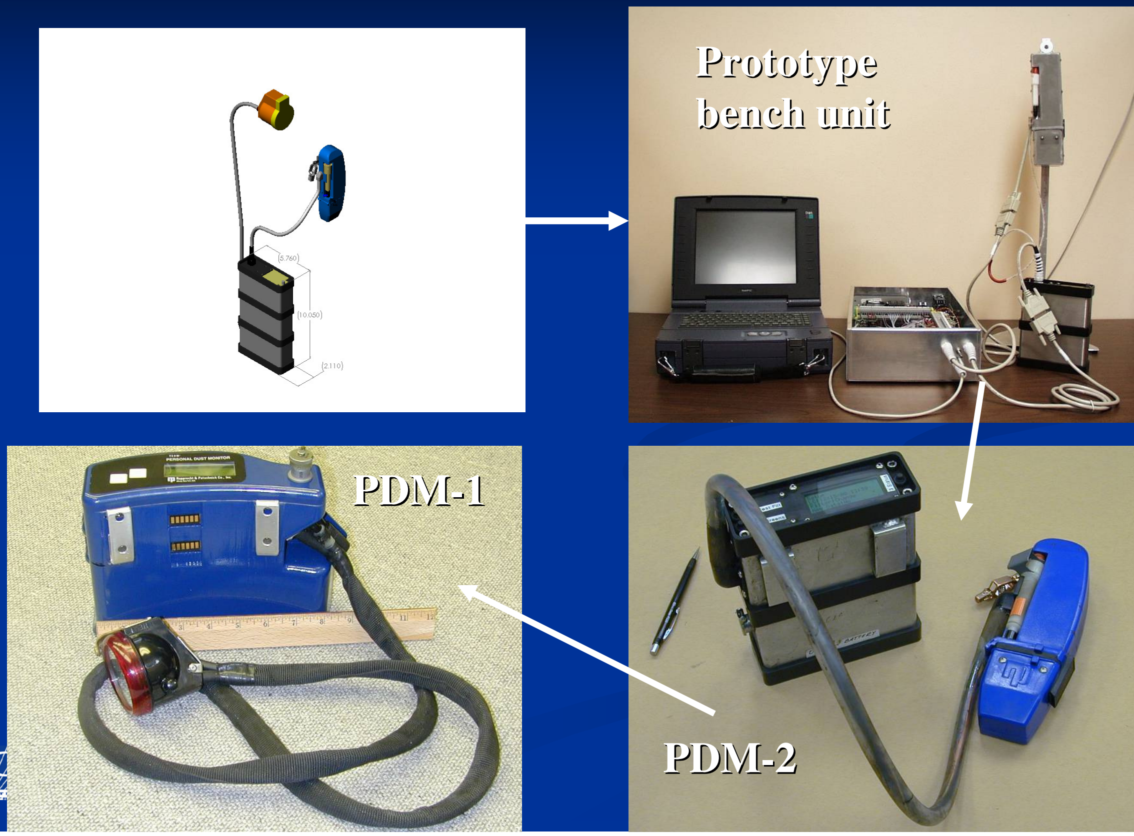
Direct reading dust monitors have been needed for a long time

Decision by MSHA and BOM in mid-1990's to develop a mass based sensor

- Initial approach used existing fixed site environmental monitor
- Mount on mining machine much like a methane monitor
- 4 cu ft box weighing 160 lbs.
- Relied on area measurements, no data on personal exposure and not reliable

Enabling technology

Evolution of PDM Technology



PDM Design Goals

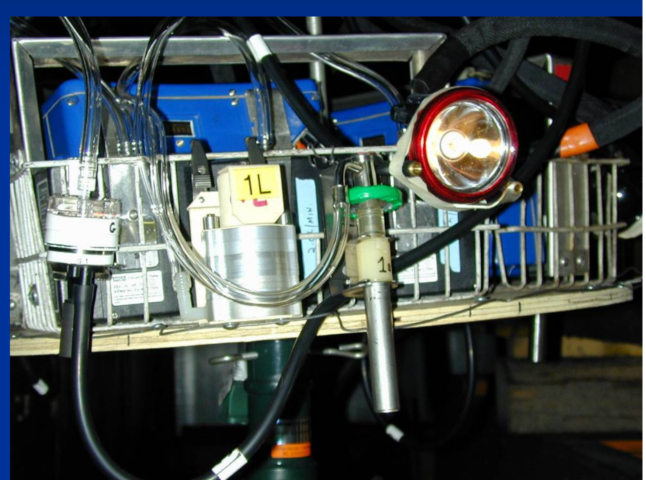
- Equivalent to or better than the current sampler
- Provide accurate EOS reading for:
  - Mass
  - Cyclone bias – kept low
- Include cyclone with low bias relative to the MRE and ISO respirable dust convention
- Compliance with MSHA intrinsic safety requirements for both sampler and cap lamp

Equivalency testing

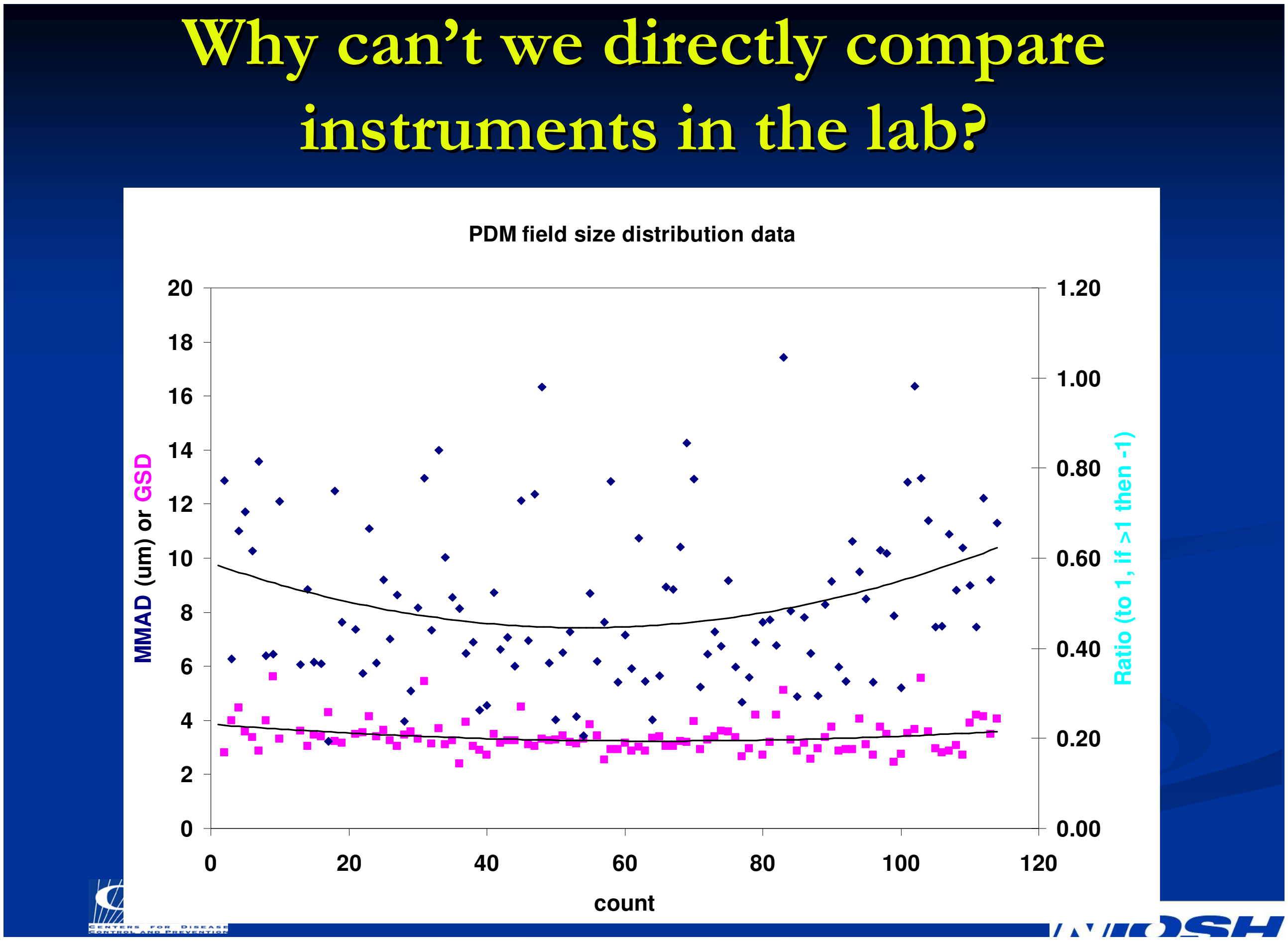
- U. S. law uses MRE equivalency
- Compare PDM directly to MRE
- Use caution when comparing between samplers -- compounds error
- Reference samplers obsolete
- Used personal impactors as reference.

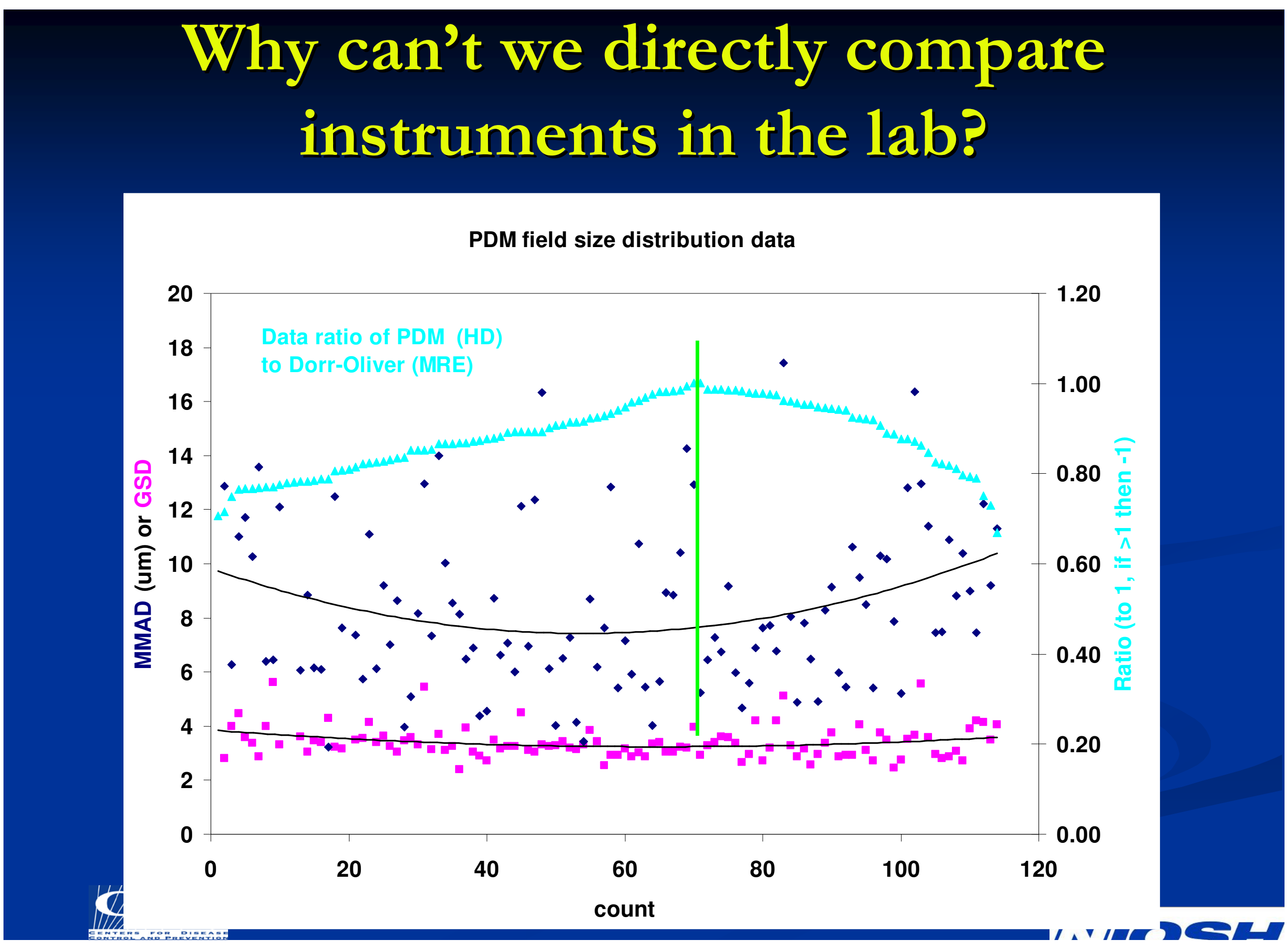
Is the mass measurement correct

- Use the best weighing procedures – QC
- Minimize variables
  - Inlet loss
  - Transport loss
  - Identical size fractionation
- Direct comparison best



NIOSH RI 9663


Why can't we directly compare instruments in the lab?
PDM field size distribution data
MMAD (um) or GSD
Ratio (to 1, if >1 then -1)
count
0
20
40
60
80
100
120
0
2
4
6
8
10
12
14
16
18
20
0.00
0.20
0.40
0.60
0.80
1.00
1.20

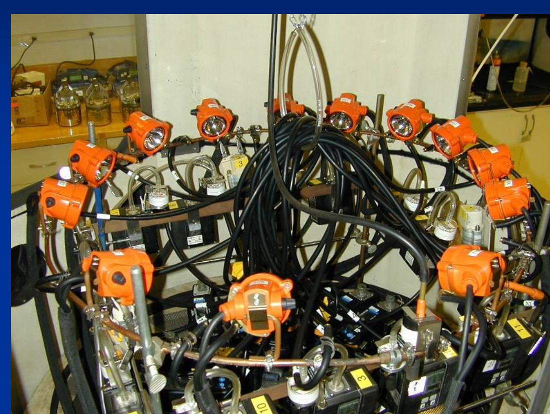

Why can't we directly compare instruments in the lab?
PDM field size distribution data
Data ratio of PDM (HD)
to Dorr-Oliver (MRE)
MMAD (um) or GSD
Ratio (to 1, if >1 then -1)
count
0
20
40
60
80
100
120
0
2
4
6
8
10
12
14
16
18
20
0.00
0.20
0.40
0.60
0.80
1.00
1.20

Break problem into testable hypothesis

- Direct mass to mass comparison – Does mass comparison meet recognized criterion?
- Direct determination of size selective bias. Is bias less than or equal to existing method?
- If both hypothesis are true, then direct field comparison of two methods over a wide range of aerosol size and type should be true.
- Confirm laboratory results with representative field sample

Results of Accuracy Criteria Testing for Mass Measurement

- Side by side triplicate reference versus PDM with identical inlets
- Variables
  - 3 coal types/ 3 size distributions
  - 50% RH, 22° C
- RI 9663 http://www.cdc.gov/niosh/mining/pubs/pubreference/outputid114.htm



Coal type	Unit serial number	Bias	RSD x/r	accuracy	Confidence Limits Upper 95%
Overall	101	-0.04	0.06	12.50	15.10
	102	-0.08	0.06	15.80	17.70
	104	-0.05	0.05	11.30	12.90
	105	-0.12	0.06	20.00	21.90

Cyclone comparison testing

- Compare results of impactor defined respirable mass fraction to triplicate cyclone collected mass fraction
- Calculate ratio and test for significance by coal/size type and overall.

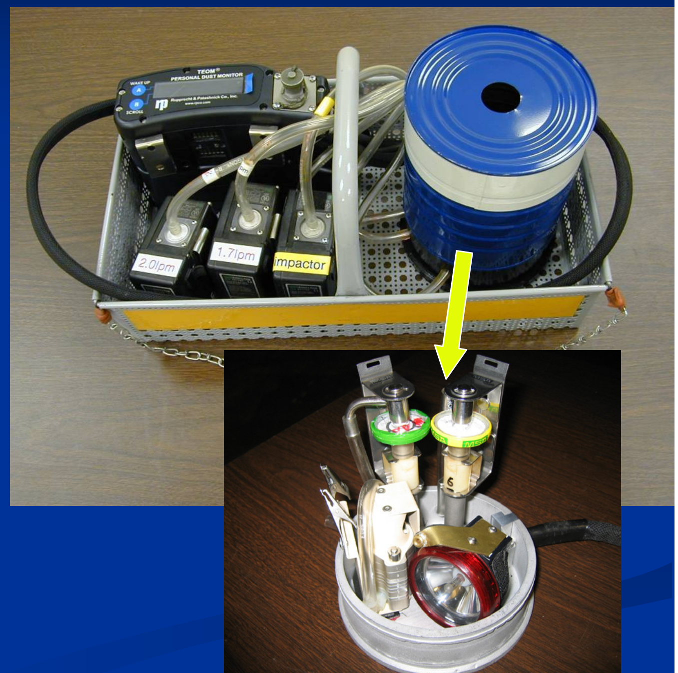
(MRE) Dorr Oliver /ISO	1.25
Higgins Dewell/ISO	1.15
(MRE)Dorr Oliver/ MRE	1.11
Higgins Dewell/ MRE	1.02

Laboratory Conclusions

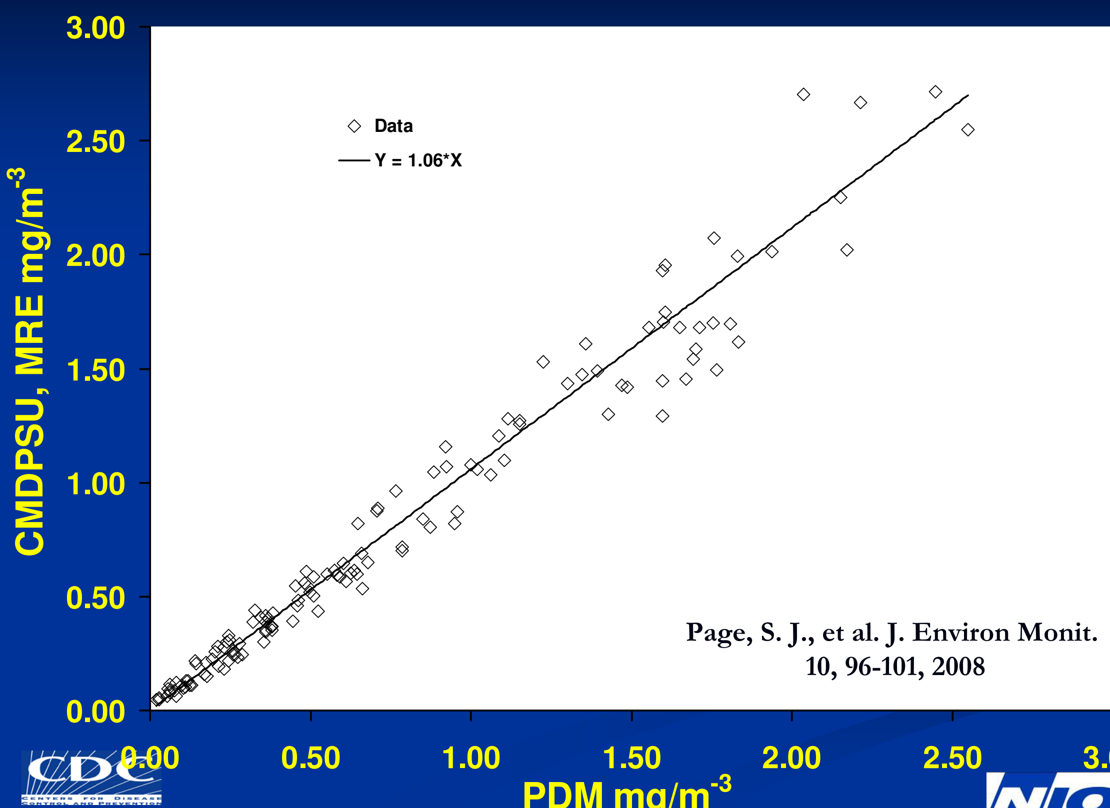
- Mass measurement by PDM meets NIOSH accuracy criteria – for an individual observation, the method gives a result that is within +/- 25% with a probability of 0.95
- And, the individual result falls within an upper or lower confidence limit of 95%
- The bias of the HD cyclone is less than the DO cyclone
- Therefore, PDM is equal to or better than existing method.

Field testing apparatus

- Chamber type sampler to minimize spatial variability
- Purpose to compare instruments
- Used central dust inlet to
  - PDM
  - Personal sampler 2 lpm
  - Personal sampler 1.7 lpm
  - Marple impactor



Field Equivalence to reference method



Conclusions

- Direct lab comparison of instruments depends on reference aerosol
- For development purposes, break problem into testable hypothesis
  - Mass
  - Size selective bias
- If end use dictates -- field test to confirm

Acknowledgements

- Joint Health and Safety Committee of the Bituminous Coal Operators and United Mine Workers,
- National Mining Association
- MSHA
- Individual mine managements
- The miners
- Thermo Fisher Scientific and formerly Rupprecht and Patashnick
- Pittsburgh Research Laboratory staff

Contact information– 412-386-6689

jvolkwein@cdc.gov

DISCLAIMER: The findings and conclusion in this presentation have not been formally disseminated by the Centers for Disease Control and Prevention and shold not be construed to represent any agency determination policy.

D.R.E.A.M. WORKSHOP

Evaluating concentration of aerosol particles in occupational hygiene using Optical Particle Counters

Peter Görner, Xavier Simon, Denis Bémer
INRS, Nancy, France

NIOSH Direct-Reading Exposure Assessment Methods (DREAM) Workshop, Washington, November 13-14, 2008

Principles of direct reading aerosol measurement

- β - gauge method
- Piezoelectric method
- Tappered element method

Classical filter, Automatic weighing

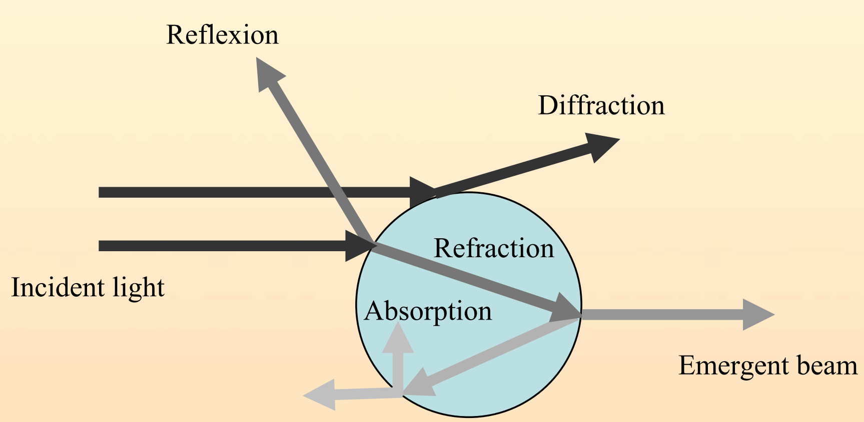
- Electrical mobility method
- Triboelectrical method

- **Optical Methods**

Optical methods

- Measurement of light transmission
  - Transmissionmeters
- Measurement of light scattering
  - Photometers
  - Optical Particle Counters (COP)

Light scattering



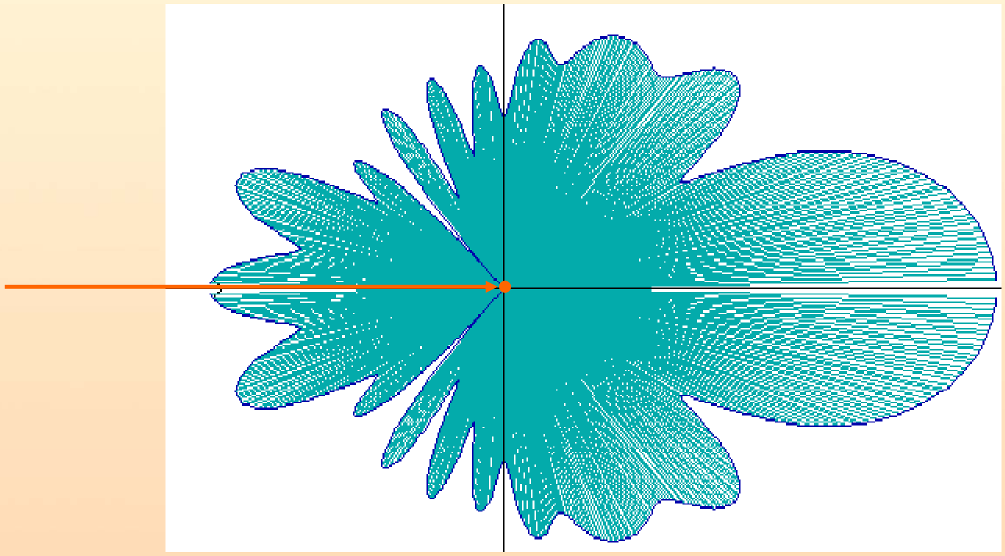
Mie's theory of scattered light (1908)

$$I = I_0 \frac{\lambda^2}{4\pi^2 \; L^2} \cdot \frac{i_1(\alpha, n, \theta) + i_2(\alpha, n, \theta)}{2}$$

I - Intensity of scattered light
I_o - Intensity of incident light
λ - Wavelength of light
L - Lenght
i_1, i_2 Intensity functions
n - Particle complex refraction index
α - Particle size parameter ($\pi d/\lambda$)
θ - Angle of scattered light observation

Spatial distribution of scattered energy

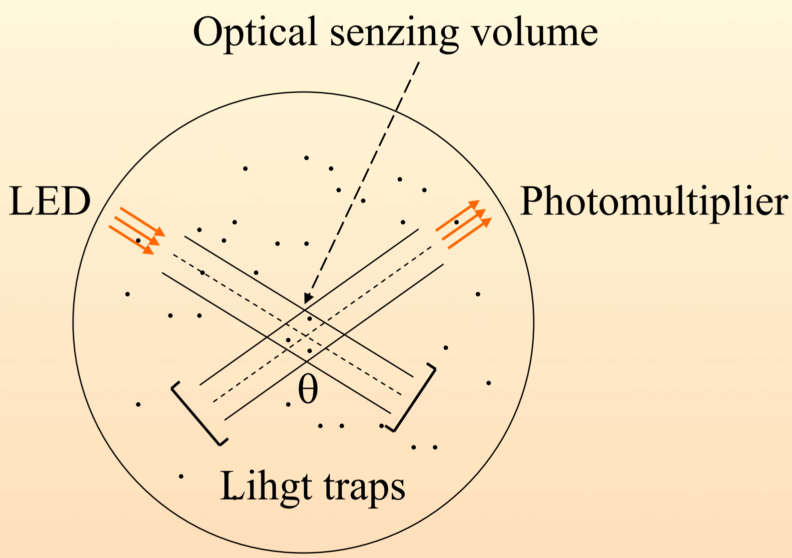
d=3 µm, n=1.5-0i, λ=960 nm, 0° < θ <360°



Apparatus to measure light scattered by airborne particles

- Photometers
- Optical Particle Counters (OPC)

Opticle cell of a photometer



Photometer does not measure any concentration

What does a photometer measure ?

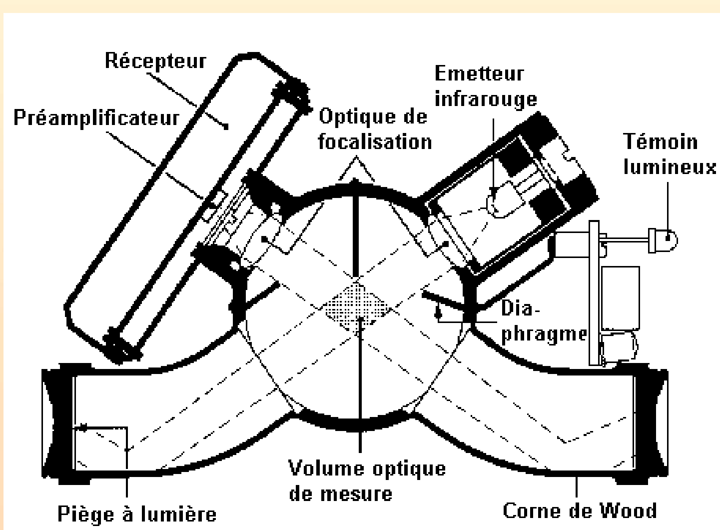
- I_o / I ratio for a particle cloud inside the optical senzing volume

- Need to be calibrated with a dust of the same n, ρ, and particle size distribution, as the measured aerosol

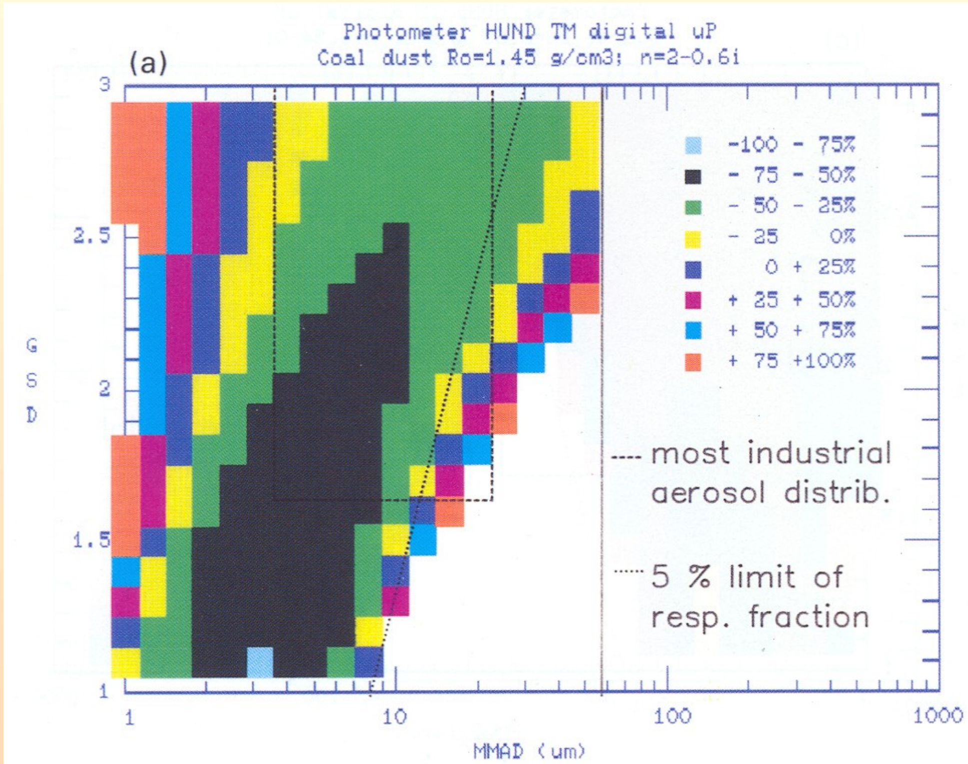
Photometer TM data (Hund, D)

Photometer HUND TM digital µP

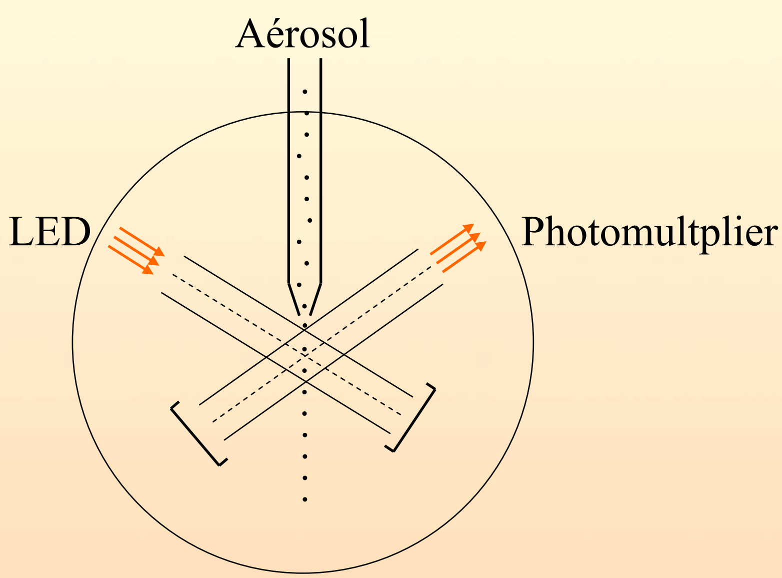
- Optical cell



Bias map of the photometer
(HUND TM digital µP)



Optical cell of a OPC



- OPC measures particle size resolved number concentration
  (Limited at about 10^3 –10^5 part./m^3)

Particle number concentration versus particle mass concentration

$C_n\ [\text{nbr.m}^{-3}] \longrightarrow C_m\ [\text{mg.m}^{-3}]$

COP response depends on: nbr, d, n
Mass concentration depends on: nbr, d, ρ

(n,ρ - particle ref. index and specific mass)

Calculation of particle mass

Particle mass of particle n_i with the diameter d_i is:

$$m_i = \sum n_i \cdot \left(\frac{\pi . d_i^3 . \rho}{6} \right)$$

Total particle mass:

$$m = \Sigma m_i$$

Conditions:
Particles are spherical with unique and known density ρ
Optically measured diameter equals the geometric d

Calculation of health-related aerosol fractions

$$C_f = C_T \int_0^{\infty} P_{t,r}(d_{ae}) \cdot F_m(d_{ae}) \cdot d\, d_{ae}$$

$d_{ae} = d\,(\rho/\rho_o)^{1/2}$ where $\rho_o = 10^3\ kg.m^{-3}$
(for spherical particles)

Standard NF X43-299, Technical Report CEN

Practical exemple

INRS Inhalable sampling head

Internal calibration filter

GRIMM 1.1 OPC

OPC: Grimm 1.108
Inhalable aerosol sampler CIP 10-I
Respirable aerosol sampler CIP 10-R

Sampling in Sausage factory. Activity: « Brushing – Coating » and packaging
Aerosol : Fungi spores ($\rho_p \approx 1000$ kg.m^{-3}) and carbonate of calcium ($\rho_p \approx 2700$ kg.m^{-3})
Aerosol particle size-distribution in mass : MMAD≈8.75 µm ; GSD≈2.15

Sampling				$\overline{C_N}$	$\overline{C_M}$ (calculation from $C_{N,i}$ by classes of dp_i)					CIP 10-I Inhalable fraction	CIP 10-R Respirable fraction
Date	Start	End	Activityr		Particles are supposed to be spherical						
					Particle specific mass						
					$\rho_p \approx 1000$ kg.m^{-3}	$\rho_p \approx 1340$ kg.m^{-3}			$\rho_p \approx 2700$ kg.m^{-3}		
				part.L^{-1}	mg.m^{-3}	mg.m^{-3}			mg.m^{-3}	mg.m^{-3}	mg.m^{-3}
05/02/2008	7h30	14h47	Brushing – Counting	637125	12,1	**16,2**	11.0	**3.8**	32,7	**16,5 ± 0,8**	**3,4 ± 0,2**
06/02/2008	7h32	15h18	Packaging	208455	3,1	**4,2**	2.8	**1.0**	8,4	**4,1 ± 0,2**	**0,76 ± 0,04**
					Inh	**Inh**	Thor	**Res**	Inh	**Inh**	**Res**

Grimm terminal filter Particle mass after 2 days sampling: 12,117 mg (INRS sampling head mounted on Grimm)
Air volume sampled in two days : 520 L (05/02/2008) + 560 L (06/02/2008) = 1,080 m^3

Average for two days

$$\overline{C_{M,Grimm}} = \frac{12,117}{1,080} = 11,2 \text{ mg.m}^{-3} \longleftrightarrow 10,1 \pm 0,5 \text{ mg.m}^{-3}$$

Limitations

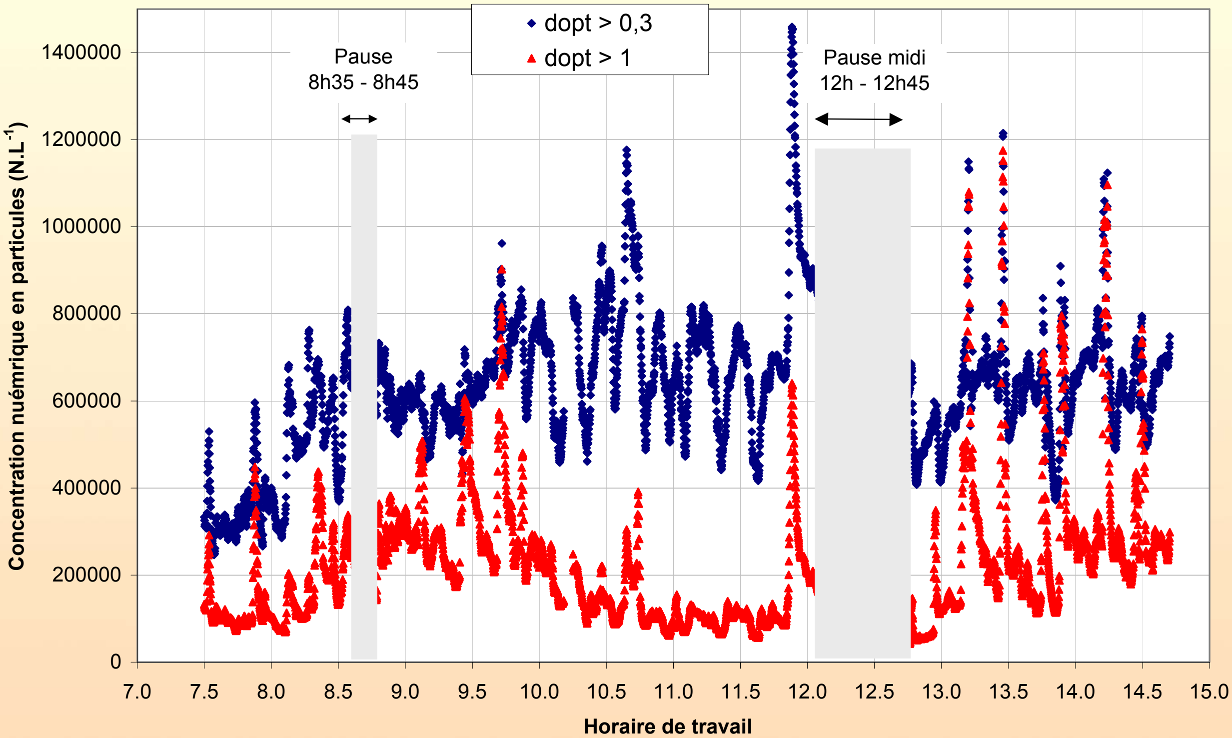
- Particle sphericity, $d_o=d_p$
- Sensibility on particle optical properties
- Unsensibility to particle density
- Necessity of in situ calibration
- Zero check
- Water haze

Advantage of using OPC in occupational hygiene

- Direct reading measurement
- Time resolved concentration profile
- Possibility of workplace mapping

- Measurement of particle size

COP - Grimm® 1.108



Time resolved concentrations for particles of two differerent sizes

Brushing–coating operation in sausage factory

D.R.E.A.M.
WORKSHOP

Real-Time Needs for Beryllium Particle Detection

Michael J. Brisson
Chairman, Beryllium Health and Safety Committee

SRNS-MS-2008-00077-S

November 13, 2008

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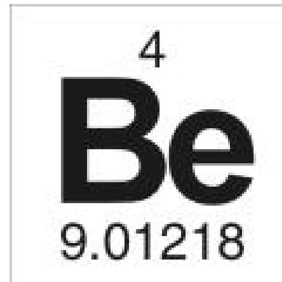
Overview

- Beryllium Uses (courtesy M. Hoover)
- The need identified
  - Overview of occupational exposure limits and current trends
  - Impact/cost of DOE Beryllium Rule
  - Recent developments within DOD
  - NIOSH NORA
- The need defined
  - What is available today
  - Benefits of direct-reading instrument
- What Has Been Tried So Far
  - Efforts up to 2002
  - Be Advanced Technology Assessment Team
  - Efforts Since 2002
- What We Need to Go Forward
  - Technology
  - Funding
- What Will Drive Further Progress?



(Source: ATSDR web site, http://www.atsdr.cdc.gov)

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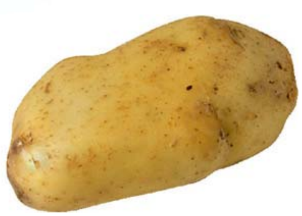
3

Beryllium is Found in ...



(aggie-horticulture.tamu.edu)

- Foodstuffs (μg per kg fresh weight – ATSDR 2002)
  - Milk (0.2)
  - Potatoes (59)
  - Crisp bread (112)
  - Kidney beans (2200)
- Soils (up to 15,000 μg/kg – USGS)
- Coal (0.2% - ATSDR 2002)
- Orchard Leaves (26 μg/kg – ATSDR 2002)
- Cigarettes (up to 0.74 μg/cigarette – ATSDR 2002)
- Minerals such as bertrandite, beryl, aquamarine, emerald

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Beryllium Properties

- Lightweight
- High melting point (1287ºC)
- Thermal conductivity
- Moderator
- Neutron reflector
- Relatively transparent to X-Rays
  - Used in windows for nondestructive analytical equipment
  - Techniques like point-and-shoot XRF not viable for Be detection

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Uses for Be Products (20% - 100%)

- Satellites and spacecraft
- Guidance systems (military and commercial)
- Brake parts (automotive, aircraft)
- Nuclear weapons (neutron reflector)
- X-Ray windows
- Optical instruments
- High-end audio
- Sports equipment

(Source:Fermilab Web site, http://www-esh.fnal.gov)

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Beryllium Alloys

(CuBe at Brush-Wellman Elmore, OH, plant, http://www.brushelmore.com)

- Copper-beryllium (CuBe)
  - Resistant to metal fatigue failure
  - Resistant to corrosion
  - Rotary-dial telephone springs
  - Non-sparking tools
- Aluminum-beryllium (AlBeMet® - Brush-Wellman)
  - Resistant to corrosion
- Nickel-beryllium
- Uses for alloys:
  - Fire control sprinkler heads
  - Aircraft landing gear bushings
  - Current-carrying springs
  - Electromagnetic shielding

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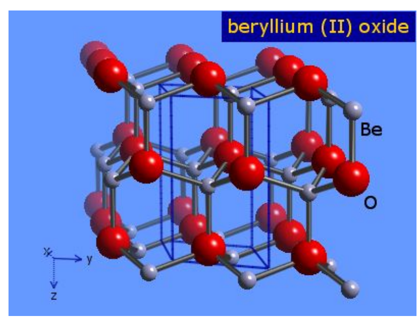
7

Beryllium Oxide

- Semiconductor parts
- Integrated circuits
- Good thermal conductivity
- Good electrical insulator
- Nuclear reactors
  - Moderator
  - Neutron reflector



(Source: WebElements™, http://www.webelements.com Used with permission)

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Occupational Exposure Limits

- ACGIH® Threshold Limit Value (TLV®) and OSHA Permissible Exposure Limit (PEL)
  - ACGIH® TLV® and OSHA PEL: 2 $\mu g/m^3$ (8-hour time-weighted average or TWA)
  - Same limit in Austria, Spain, France, Sweden, U.K., and Ontario
    - Denmark: 1 $\mu g/m^3$
  - Originally proposed in 1949 from Atomic Energy Commission studies
  - ACGIH® adopted TLV® in 1959 for beryllium; applied to "beryllium and compounds" in 1986
- Short-term exposure limits (STEL)
  - Maximum exposure for any 15-minute period
  - U.S.: 5 $\mu g/m^3$
  - Austria: 8 $\mu g/m^3$
  - Denmark, Hungary: 2 $\mu g/m^3$

(Source: Lawrence Livermore National Lab)

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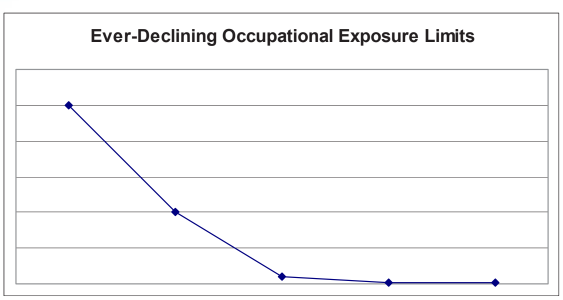
OEL Trends



(Illustration only)

- In 1990's, learned that the 2 $\mu g/m^3$ PEL/TLV level is not necessarily protective
  - Incidences of sensitization and CBD at lower exposure levels
- ACGIH has proposed several new TLVs since 1999
  - Current proposal: TLV of 0.05 $\mu g/m^3$ and STEL of 0.2 $\mu g/m^3$ (pending since 2006)

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OEL Trends (2)

- OSHA
  - Rulemaking has been in progress since 2002
  - Currently evaluating range of exposure limits (0.1 – 1.0 $\mu g/m^3$ air)
- State of California
  - 2006: exposure limit of 0.2 $\mu g/m^3$ (air), equal to DOE action level
- Quebec Province
  - 2006: exposure limit of 0.15 $\mu g/m^3$

Bottom line trend: lower OELs

- Potential challenge for any direct-reading instrument

It's like the game of limbo …
How low can you go???
(picture from nyiboosterclub.org)

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DOE "Beryllium Rule" (10CFR850)

- Effective January 7, 2000
- Response to exposure concerns in DOE nuclear facilities
- Action level of 0.2 $\mu g/m^3$ (air, 8-hr TWA)
- Housekeeping within Be areas: 3 $\mu g/100cm^2$ (surface)
- Release to non-Be area: 0.2 $\mu g/100cm^2$ (surface)
  - Based on lab capabilities at that time – not health-based
  - OSHA, ACGIH® do not have surface wipe action levels like DOE; however, Quebec (IRSST) also does surface wipe measurements
- Measurement uncertainty within $\pm$25% at action level

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Impact of DOE Beryllium Rule

SUMMARY: The Department of Energy (DOE) is today publishing a final rule to establish a chronic beryllium disease prevention program (CBDPP) to reduce the number of workers currently exposed to beryllium in the course of their work at DOE facilities managed by DOE or its contractors, minimize the levels of, and potential for, exposure to beryllium, and establish medical surveillance requirements to ensure early detection of the disease. This program improves and codifies provisions of a temporary CBDPP established by DOE directive in 1997.

EFFECTIVE DATE: This rule is effective January 7, 2000.

(64 FR 68854, 12/8/1999)

- Establishment of "beryllium inventory"
- Action levels at one-tenth the OSHA PEL
- Surface wiping as well as air sampling
- Operational impacts
  - Delays in receiving analytical results
  - Costs from sampling and analysis (over $3 million/year at some sites)
- Result: need for "real-time" monitoring capabilities
  - Improved worker and public protection
  - Improved productivity
  - Reduced lab and operating costs

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Recent Developments Within DoD

- In 2007, beryllium added to Emerging Contaminants List
  - Contaminants of emerging concern to DoD due, for example, to potential regulatory changes such as lower OEL's
- Two-part National Academy of Sciences study
  - Commissioned by U.S. Air Force
  - Essentially recommends approach similar to what DOE adopted in 10CFR850

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Beryllium and NIOSH NORA

- NIOSH National Occupational Research Agenda (NORA)
  - Partnership between NIOSH and Brush-Wellman originated in 1998
    - Basic epidemiology, exposure characterization, risk factor research
    - Development of enhanced worker protection model
    - Evaluate effects of model on worker risks
    - Communicate results throughout beryllium-using community
  - Received one of two 2008 NORA Innovative Research Awards
  - Partnership ongoing

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Why a Beryllium Direct-Reading Instrument (DRI)?

- Current detection methods are laboratory-based
  - Collect samples in field and take to laboratory
  - Digest samples into acid solution or extract into ammonium bifluoride solution
  - Analyze via spectroscopy (ICP-AES, ICP-MS, GFAA) or fluorescence
    - ICP-AES most common in U.S.
    - May not be sensitive enough for proposed ACGIH TLV (8-hour or STEL)
  - Delay factor of 24 hours (best) to >1 week
    - Costly for ongoing processing operations

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A Be Field Analyzer Wish List

- The “black box” wish list:
  - Real-time air monitor and surface wipe analyzer (ideally the same device)
  - Reporting limits comparable to lab analysis
  - Avoid/minimize liquid waste
  - Portable (NOT just “transportable”)
  - Easy to use and maintain
  - Cheap
- A beryllium DRI would be ideal (this is the DREAM conference, right?)

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Potential DRI Benefits

- Could save millions per year in analytical costs for DOE alone
- Would improve worker protection by providing faster results
- Within DOE, most needed for surface sampling, but also needed for air monitoring
  - NAS study recommends housekeeping for which a surface DRI would be beneficial
- For aerosols, DRI could eliminate issue of wall deposits
  - Current air sampling uses closed face cassettes (CFC) of 25 or 37 mm
  - Some particulate collects on interior walls
  - Most labs only analyze filter catch
  - May underestimate Be to which workers are exposed

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Potential DRI Issues

- Issues Common to Aerosols and Surfaces:
  - Validation
  - Cost and Portability
  - Detection Limits
  - Precision at low µg per sample levels (must be within $\pm$25% of 0.2 µg per sample for DOE Beryllium Rule)
  - New technologies may need to be developed
  - DRI for both aerosols and surfaces may not be possible

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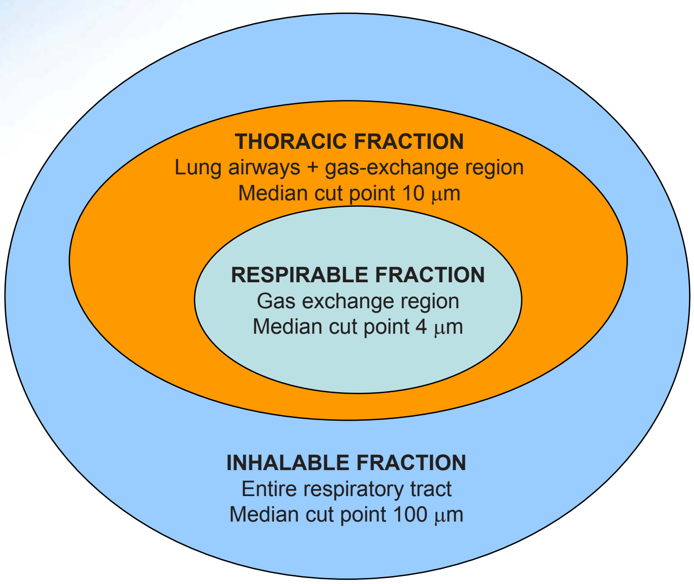
DRI Issues (2) – Size-Selective Sampling



- ACGIH® NIC proposes inhalable fraction
  - Current U.S. practice does not follow any of the ISO sampling conventions
  - Would require larger air volume
  - Would shift focus away from fine (0-4 µm) particulate
- Aerosol DRI would need to address size-selective sampling requirements

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DRI Issues (3) – Surface Sampling

- Nature of surfaces being wiped
  - Dimensions, porosity, roughness
- Amount of particulate (Be and otherwise) on surface
- Oils, greases, other potential interferences

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Early Efforts, 2000-2002

- Efforts at several DOE sites involving various technologies
- Efforts not coordinated
- Early attempt at comparing efforts was First Symposium on Be Particulates and Their Detection
  - February 2002, Santa Fe, NM
  - Sponsored by DOE Network of Senior Scientists and Engineers and Los Alamos National Lab

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Early Efforts (2)

- Laser Induced Breakdown Spectroscopy (LIBS)
  - Direct-solids technique
  - Pros
    - No liquid waste
    - One unit has air and wipe models
  - Cons
    - Not validated at multiple labs or field sites
    - Issues with precision at low $\mu g/m^3$ range
    - One unit requires cart
  - Not being actively pursued

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Early Efforts (3)

- Microwave Induced Plasma Spectroscopy (MIPS)
  - Developed at Los Alamos National Lab in 2000
  - Has since been commercialized
  - Issues with precision at low $\mu g/m^3$ range
  - Additional validation work needed
  - Not being actively pursued

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Early Efforts (4)

- Anodic Stripping Voltammetry
  - ELS Technology
  - Beryllium-specific
  - Portable
  - Generates liquid waste
  - Needs additional validation
  - Vendor interest has waned due to perceived low demand

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Early Efforts (5)

- Time of Flight Mass Spectroscopy (TOFMS)
  - Transportable, not portable
  - Precision at low $\mu g/m^3$ range not well demonstrated
  - May be closer than LIBS, MIPS, or ASV; still some interest
  - Costly

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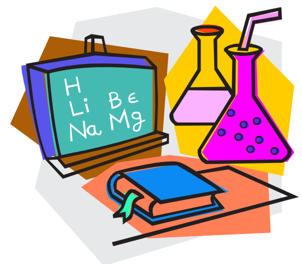
Early Efforts (6)

- Others presented at February 2002 Symposium
  - Aerosol-Focusing LIBS (Oak Ridge/Y-12)
  - Surface-Enhanced Raman Scattering (Oak Ridge/Y-12)
  - Amzil Beryllium Air Monitor (no longer in business?)
  - Colorimetric wipes (LANL)
- Issues common to all:
  - Incomplete validation
  - Standard method not established/published (needed for AIHA accreditation purposes)
- Bottom line: un-coordinated efforts did not produce needed outcome



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Be Advanced Technology Assessment Team

- NSSE established Beryllium Advanced Technology Assessment Team (BeATAT) after February 2002 symposium
- Key outputs of BeATAT:
  - Assessment Report
  - Draft Criteria for “Real-Time” Equipment
- Final report: June 2003

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BeATAT Report

- Criteria development
  - Draft criteria completed December 2002
  - Separate criteria for air monitoring equipment and surface wipe analysis equipment
- Key Elements of Criteria
  - Terminology
  - Minimum Technical and Operational Specifications
    - Functionalities
    - Requirements
  - Technical Evaluation Criteria
  - Field Evaluation Criteria
- Focus on field-deployable, but not necessarily direct-reading, instrumentation

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BeATAT Report – Selected Functionalities

- Common Functionalities
  - Reporting range of 0.05-5.0 $\mu g/m^3$ (air) or μg/wipe
    - Measurement uncertainty within $\pm$25% throughout range
    - *This range may no longer be adequate given ACGIH proposed TLV*
  - Calibration
    - Covers full reporting range
    - Little or no disassembly required
  - Quality Control
  - Battery operation or backup
  - Data downloading

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BeATAT Report – Selected Functionalities (2)

- Functionalities for Air Monitoring Equipment
  - User-selectable air sampling rate of 10-50 cfm
  - Aerodynamic particle sizing capabilities
    - Particle number, surface area, mass per m^3
    - Important to mimic size-selective inhalation characteristics
  - Digital alarm with selectable setpoint (range TBD)
  - Report results in $\mu g/m^3$
- Functionalities for Surface Wipe Equipment
  - Report results in $\mu g/100cm^2$

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Efforts Since 2002

- Berylliant Fluorescence Analyzer
  - Specific for Be
  - Lab-Validated
  - Accepted by AIHA for accredited beryllium analysis
  - Not direct-reading or real-time
  - Generates liquid waste
- Second Symposium on Beryllium Particulates and Their Detection (2005)
  - Aerosol TOFMS (Y-12)
  - Raman spectroscopy (ORNL/Y-12)
  - Colorimetric wipe improvements

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Efforts Since 2002 (2)

- Beryllium Health Research Agenda
  - Originated by NNSA Defense Programs in 2006
  - Ambitious agenda:
    - Real-time monitoring for both aerosols and surface samples
    - High-volume personal air pumps
  - Funding provided only in FY06, not subsequent years
  - No further progress expected

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What We Need to Go Forward

- Technology
  - We have not really tried to find a DRI technology that would work for Be
  - Technologies like XRF will not work for Be due to its transparency to X-Rays
  - Thus, some technology development required
  - Technology for aerosols and for surfaces may or may not be the same
- Funding
  - Single-source approach to obtaining funding no longer viable
  - Multi-year effort needed to develop and deploy viable technology

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What Will Drive Further Progress?

- Beryllium needs to be seen as more than a DOE issue
  - NAS study for Air Force may help
- Benefits for a real-time device (such as DRI) need to be more widely understood
  - Improved worker protection
  - Significant cost savings
  - Process improvements
- Collaboration on funding is needed
  - Multiple groups/sources kicking in for joint projects

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Acknowledgements

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- Sam Johnson (NNSA)
- David Weitzman (DOE)
- Donna Cragle (Oak Ridge Associated Universities)
- Melecita Archuleta (Sandia National Lab)
- Other BHSC members

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For More Information

Mike Brisson, BHSC Chair
803-952-4400
mike.brisson@srs.gov

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D.R.E.A.M.
WORKSHOP

The Use of Direct Reading Methods to Evaluate and Demonstrate the Effectiveness of Engineering Controls in Construction

Pam Susi, CPWR and
Dr. John Meeker, U. of Michigan
DREAM Workshop,

The Center to Protect Workers' Rights (CPWR)

- Research arm of the Building & Construction Trades Council, AFL-CIO
- Conducts research aimed at improving quality of life for construction workers
- Conducts training in safety and occupational/environmental health
- Provides medical screening to former DOE workers

CPWR Safety & Health Research Program

- Cooperative agreement with NIOSH since 1991
- Consortium of university researchers and CPWR staff researchers
- Active involvement of building trades unions
- Currently involved in a 5 year cooperative agreement with NIOSH (2004 – 2009)

Construction Training Initiatives:

- NIEHS Training (approx. 4,000 workers/yr)
  - EPA Superfund Sites
  - Department of Energy Sites Nationwide
  - Urban Brownfields & Minority Worker Training
- OSHA Training Institute Education Center
- Disaster Response Training


construction
solutions
work hazards, and options
for making work safer
Identifies Workplace Risks- and provides Solutions for Reducing those Risks
Trade/ Occupation
Task / Work Activity
Hazard Analysis
Solutions
www.cpwrconstructionsolutions.org


construction
solutions
work hazards, and options for making work safer
Masonry, Cement & Plaster
This work includes activities such as laying brick, block or stone, troweling surface materials (including plaster), concrete work, and restoring brick, block or stone structures. This database includes an analysis of the hazards associated with these activities, as well as practical measures for making such work safer.
Select Task:
Cutting bricks, blocks, stone, concrete, tile or terrazzo
Select Hazard:
- Please Select a Hazard -
- Please Select a Hazard -
Construction dust
Lifting and Carrying (Manual Materials Handling)
Noise
Silica
Skin contact with chemicals
Stooped postures
Stressful hand & wrist activity
Vibration
Ho
© 2008, Devel

Hazard Analysis

Work Activity:	Masonry, Cement & Plaster
Task:	Cutting bricks, blocks, stone, concrete, tile or terrazzo
Hazard:	Construction dust

Problem:	Construction dust generated by cutting bricks, blocks, stone, concrete, tile or terrazzo, in combination with other dust exposures, can cause chronic bronchitis and emphysema.
Risk Description:	Chronic obstructive pulmonary disease (COPD) includes chronic bronchitis and emphysema. ***Chronic bronchitis*** is present when someone has a regular cough with phlegm for at least 3 months ayear for two years. ***Emphysema*** is present when there is destruction of the walls of the airspaces of the lung.The destruction of airspaces means there is less lung surface; loss of lung surface reduced the ability of the lung to transfer oxygen into the blood stream. More Detail
Level of Risk:	Work loads or activities are of such a magnitude and character that all or most workers risk developing an MSD in the short or long term. More Detail
Assessment Info:	You must determine whether exposures at your jobs exceed allowable limits for overall dust and specific dusts. The current OSHA standard for overall dust which contain < 1% silica is 15 mg/m3; see 29 CFR 1926.55. There are different limits for silica and welding (see information in this database for additional specific exposure limits, assessment and solutions for silica and welding). The NIOSH recommended exposure limit for crystalline silica dust is 0.05 mg/m3. NIOSH research shows that controlling exposures below this concentration should prevent all workers from obtaining silicosis. More Detail
Solutions:	For Contractors Masonry Saw with Vacuum, Bosch For Workers Good Work Practices for Minimizing Exposure to Silica Dust Suggest a Solution
Regulations & Standards:	See Regulations & Standards Detail

Characteristics of the Construction Industry

- Non-fixed, non-routine and complex work environment
- Skills intensive (with varied work process)
- Trades represent a large variety of occupations with many specialty areas in each
- Management is highly stratified with project managers, general contractors and many types of sub-contractors creating job sites where layers of contracts often distance workers from owner or primary contractor requirements

Sources of Variability in Construction

- Number of workers generating contaminants
- Materials & equipment
- Site conditions (e.g. open/enclosed work spaces)
- Use of engineering controls (often lacking)
- Market conditions (e.g. union density; regulatory & business climate; unemployment)
- Work practices (both contractors & employees)

How we've used direct reading instruments

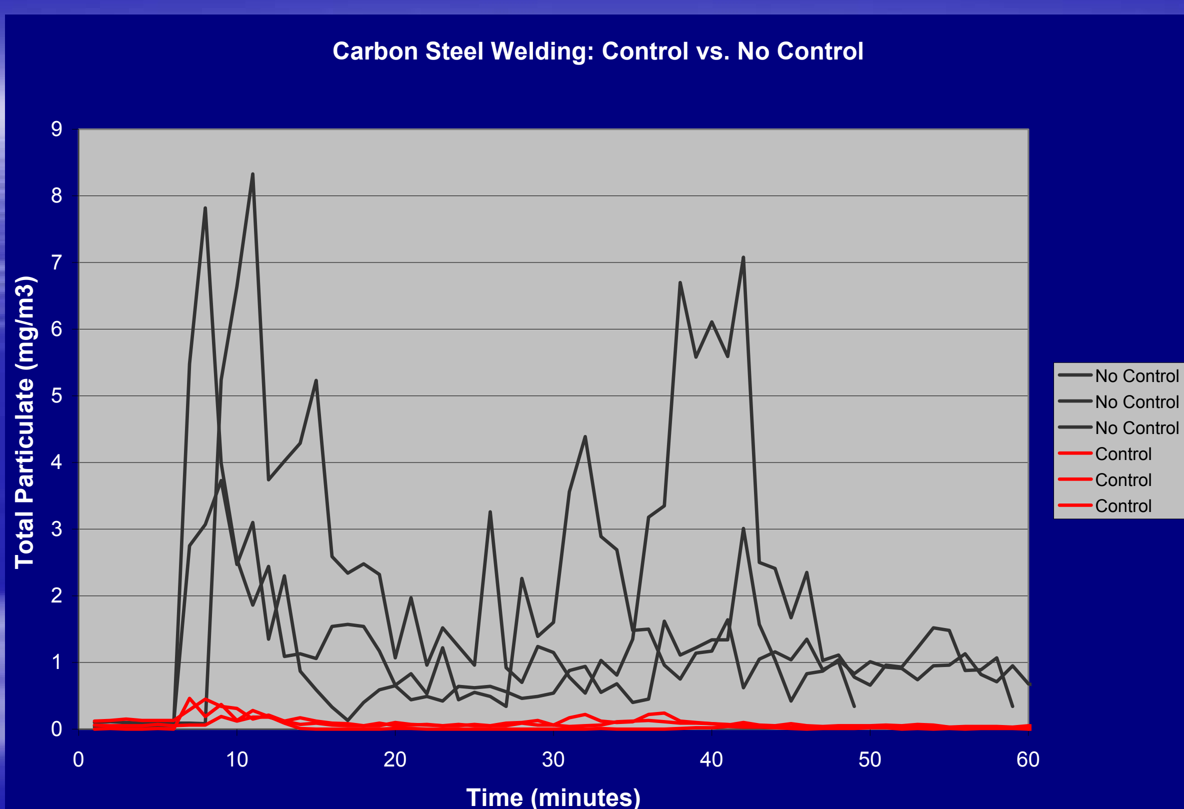
- To evaluate control technologies for silica dust generated by masonry work and fumes generated by welding
- To communicate the impact of engineering controls and work practices
- Verifying clearance of airborne contaminants during controlled trials testing control technologies

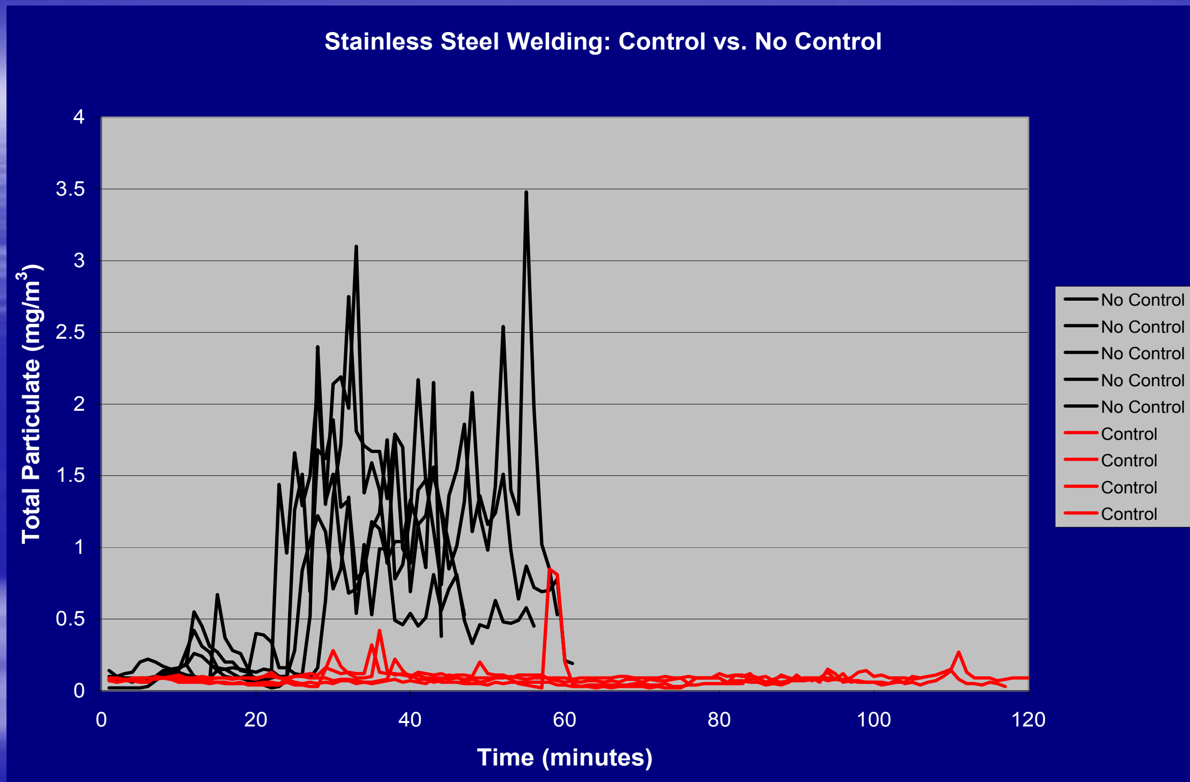
Use of Direct Reading Instrument for Welding LEV

- Performed repeat welds 6" pipe coupons
  - Schedule 40 carbon steel (Manganese)
  - Stainless steel (Hexavalent chromium)
- With and without LEV use – Random order
- multiple welds performed for each run
- Air cleared between runs – Hazdust®

Measured Variables

- Static pressure measurements of ventilation flow
- Arc time
- Sample time
- Direct reading of total particulate in vicinity of welder
- Integrated Mn or Cr(VI) concentrations



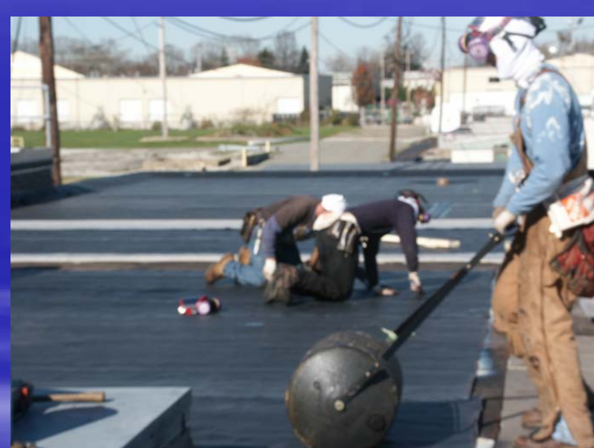


Use of Direct Reading & Video Overlay to Communicate Impact of LEV

Other applications of direct reading in construction

- Determining transient exposure levels of very hazardous agents
  – MDI & Roofing
  – Contaminated soils during excavation work
  – Benzene releases at oil refineries
- Confined spaces

Use of MDI in Roofing Adhesives



Refinery work – benzene releases


Propylene Loading
Chemicals
36 Contractor Gate
Contractor Parking
4 Gate
Barrel House

Confined Spaces

Barriers to greater use of direct reading instruments

- Cost
- Specificity or non-specificity of instruments
- Regulatory infrastructure encourages integrated sampling
- Know how among those who could benefit by use of direct reading instruments


D.R.E.A.M.
WORKSHOP

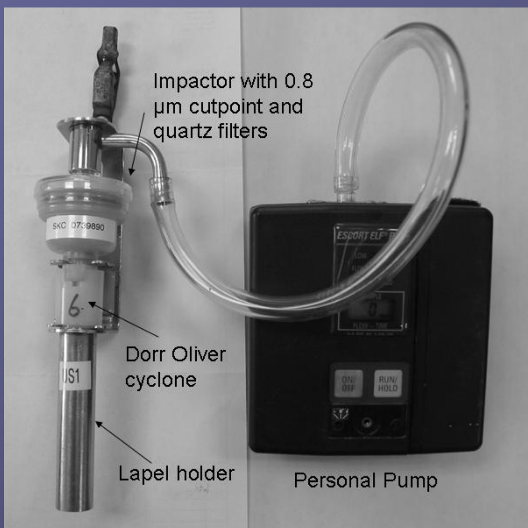
Reducing exposures to diesel particulate matter (DPM) using direct-reading instruments

Jim Noll
Center of Disease Control
National Institute for Occupational Safety and Health
Pittsburgh Research Laboratory

DPM is considered a potential health hazard

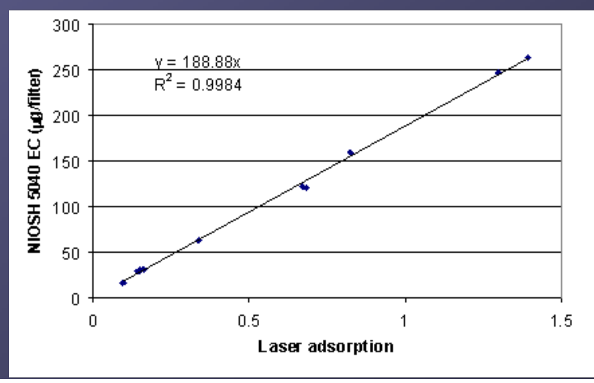
Workplace exposures can be significantly higher than environmental concentrations

In the standard method, DPM is collected on quartz filters and analyzed for elemental and total carbon using NIOSH method 5040

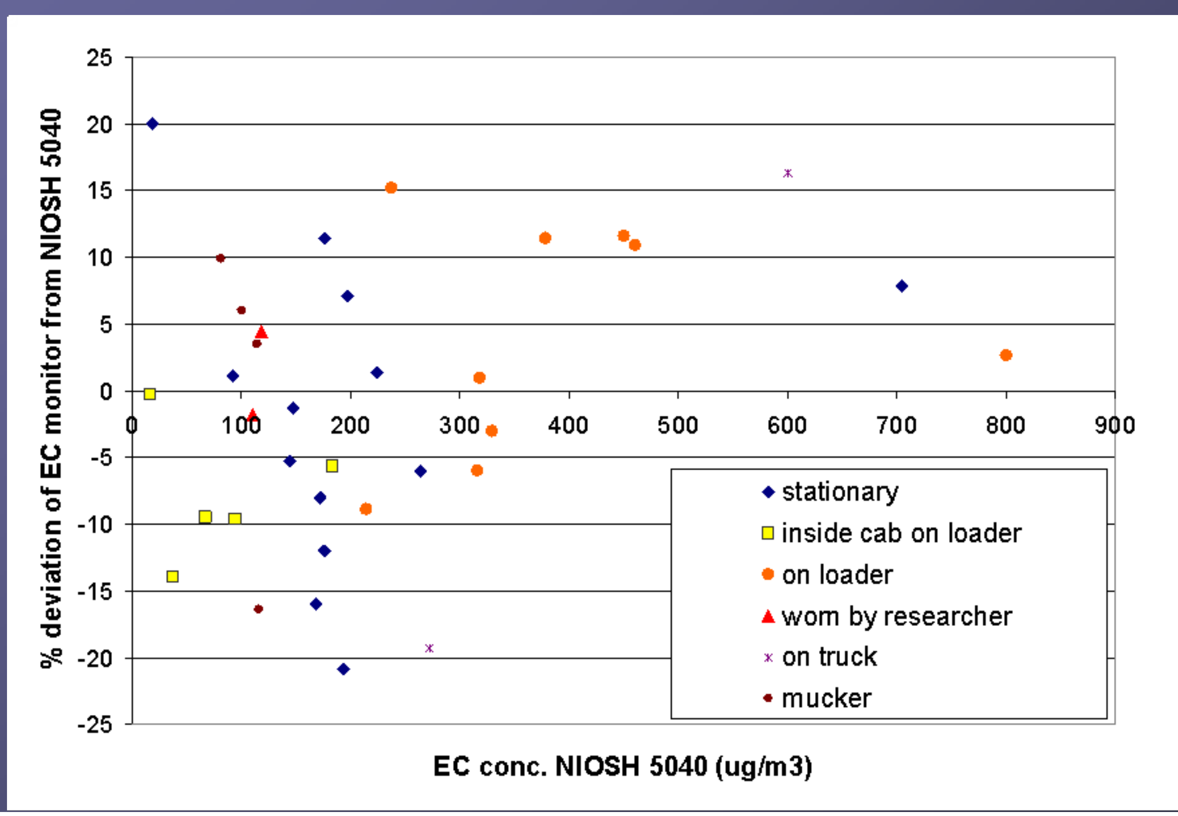


Standard method can take weeks to get results and only gives the average concentration.

NIOSH has developed a near real time monitor that measures the darkness of the filter.



EC monitor measured accurately in field



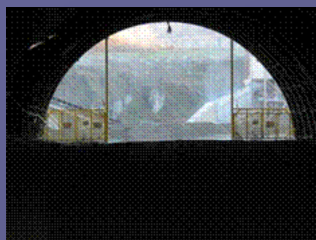
Great tool for reducing DPM exposures

EC monitor can help evaluate control technologies

Ventilation

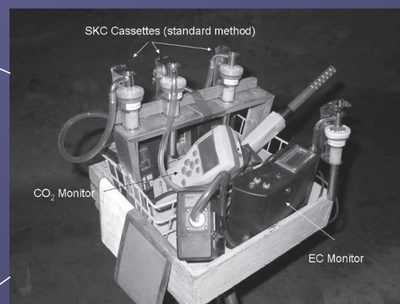
Enclosed Cabs

Area samples were taken in several underground stone mines



intake

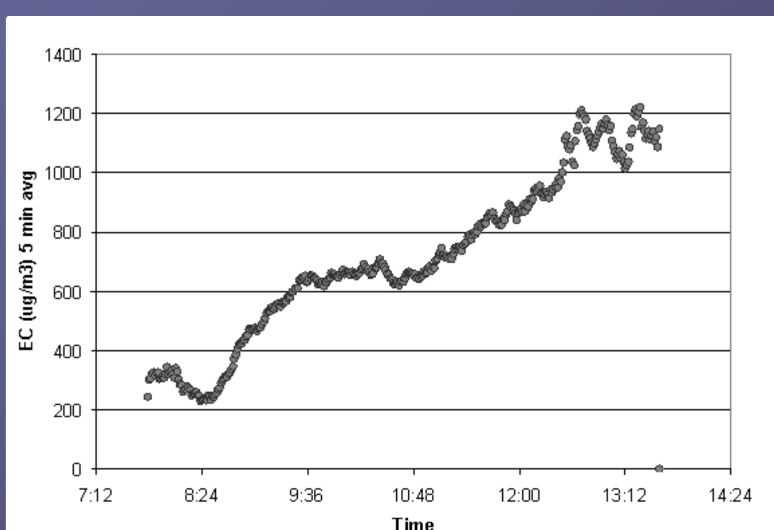
Working area or face



return

crusher

EC monitor not only showed the average concentration but also that DPM was building up and not being flushed out by fresh air.

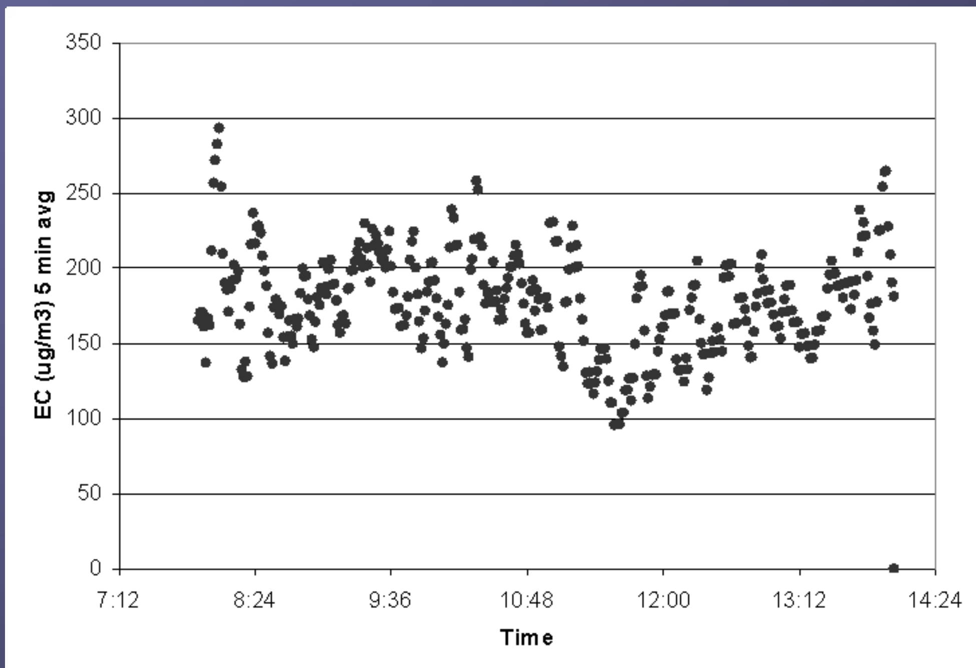


Average Concentration

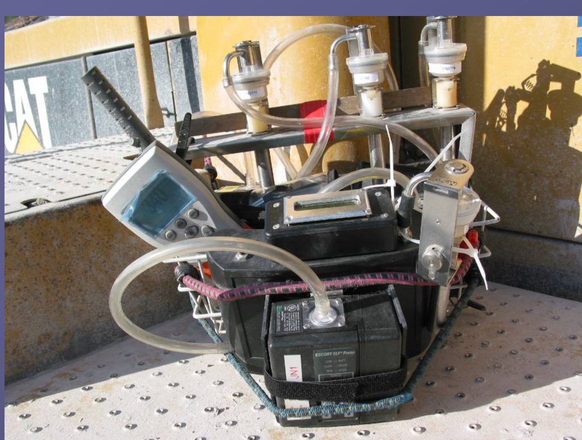
NIOSH 5040: 653 $\mu g/m^3$ EC

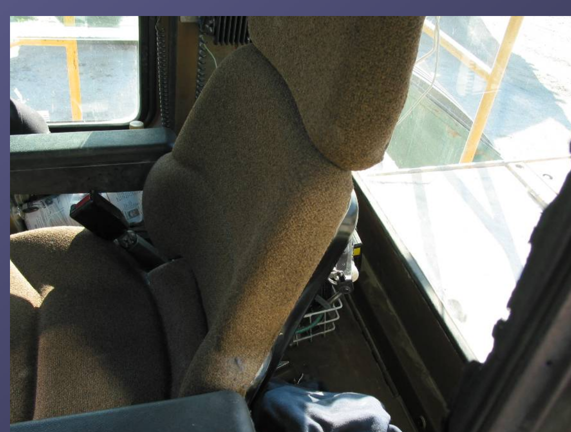
EC monitor: 704 $\mu g/m^3$ EC

The ventilation was flushing the DPM out at the crusher.

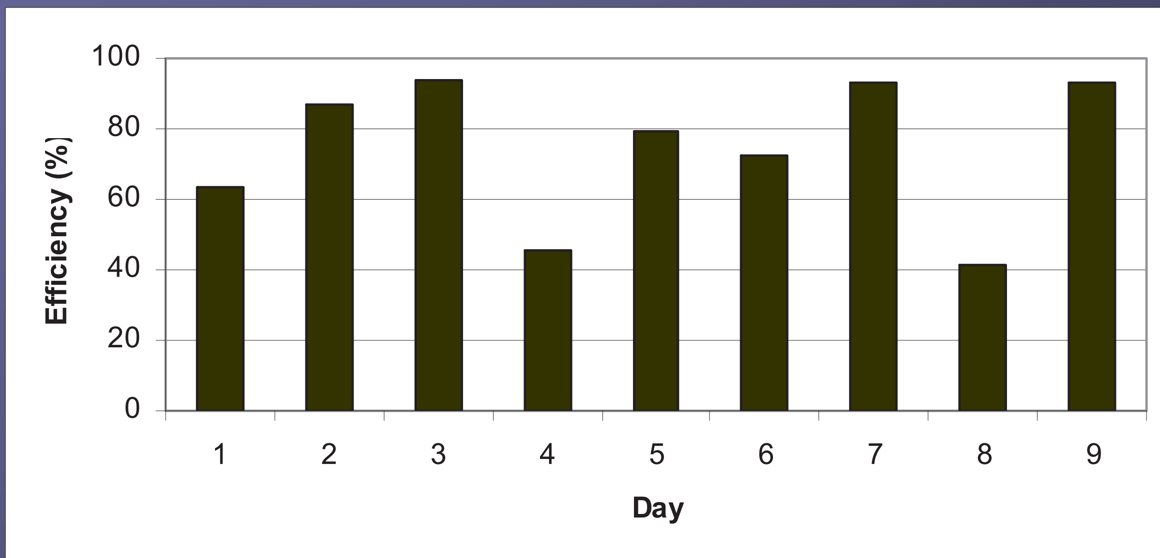


Measured EC inside and outside of cab

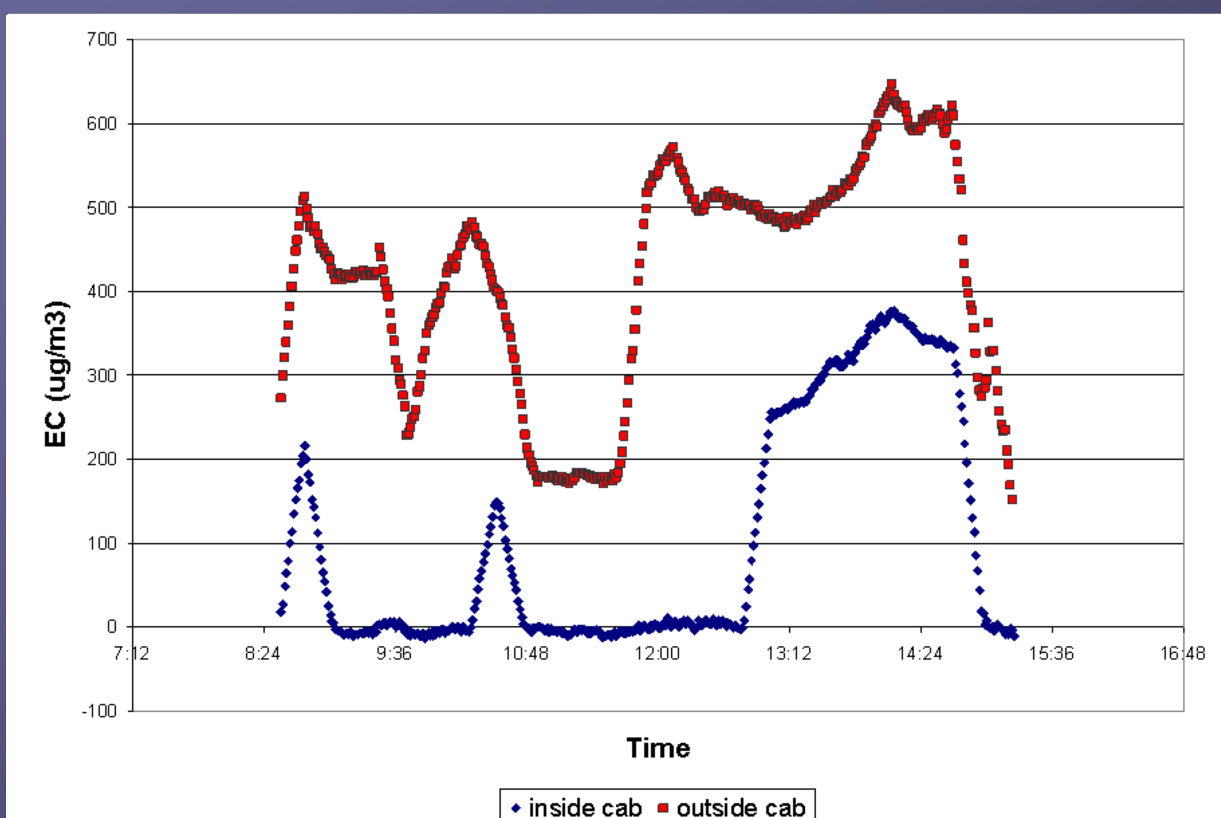




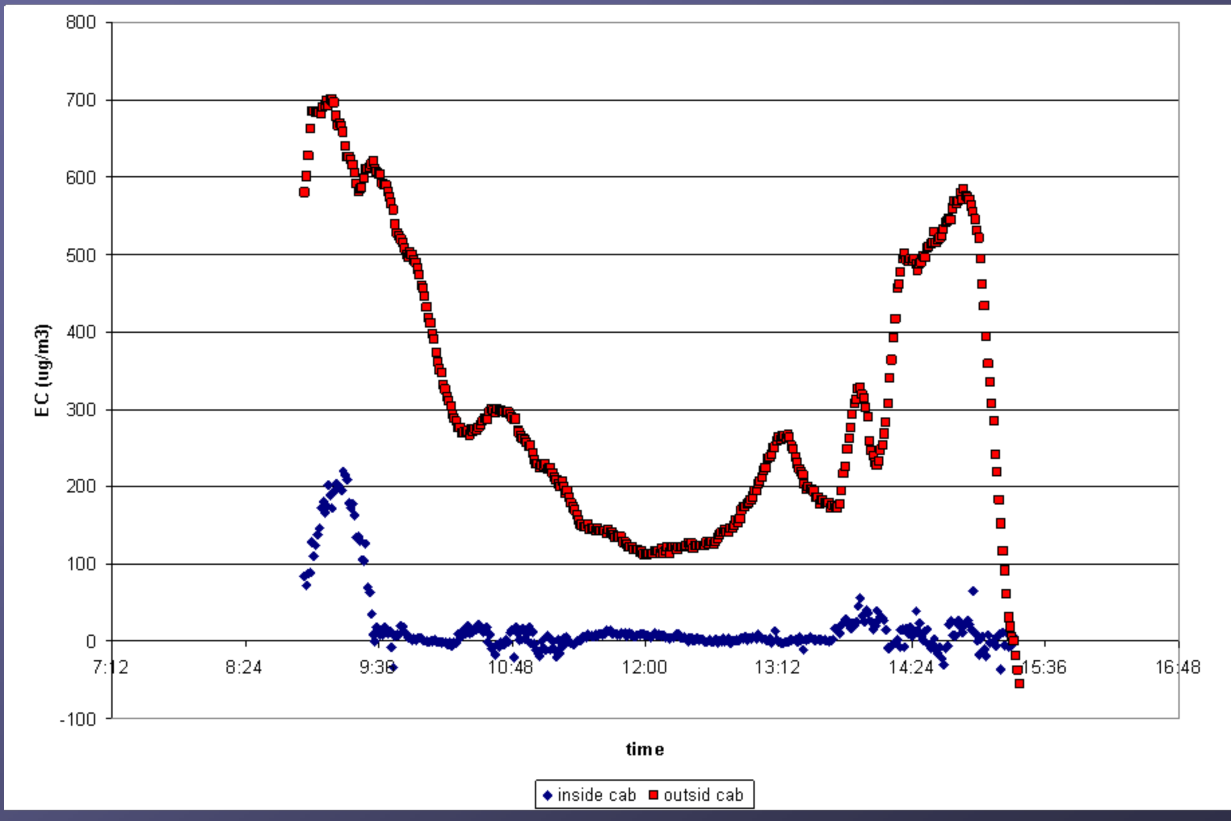
Using 5040 data, cab efficiencies ranged from 40-93%



Day 6:
73% efficiency



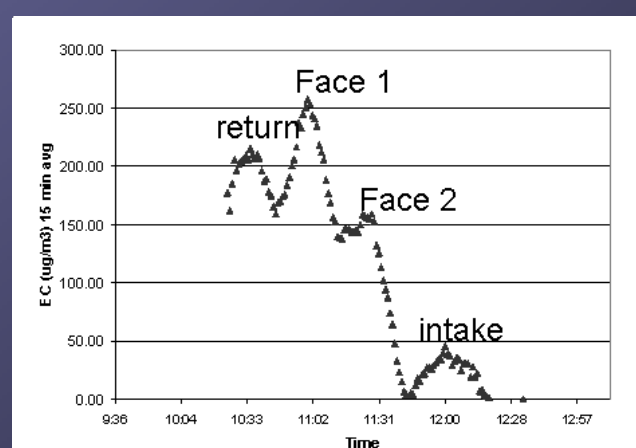
Day 9:
93% efficiency



The cab was probably over 90 % efficient in removing diesel particulate

Determine control technology failures

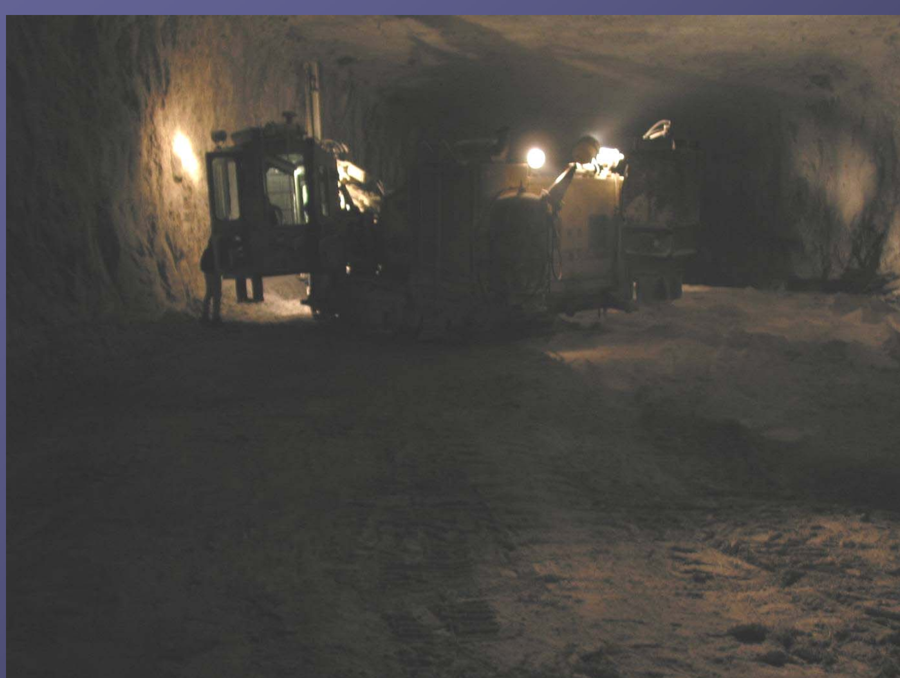
A worker can control own exposure



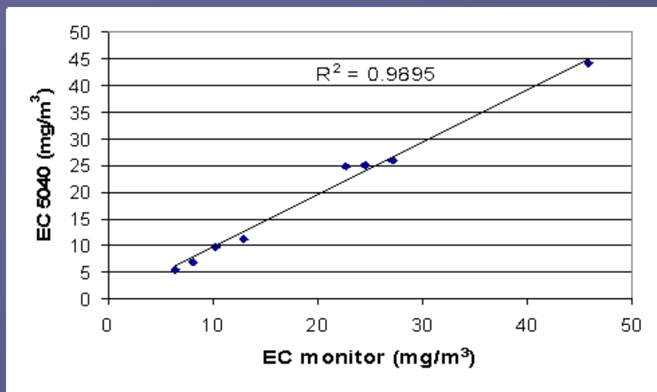
Control location of workers

- Example
  - Blasters in a stone mine that cannot work in enclosed cab
    - set location to blast in low DPM concentrations

Control the number of vehicles in an area



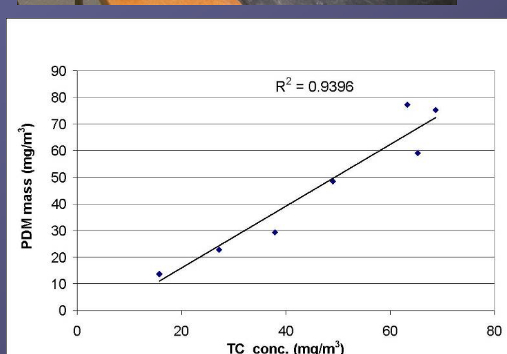
Tailpipe Evaluation



Determining DPF failure

Maintenance

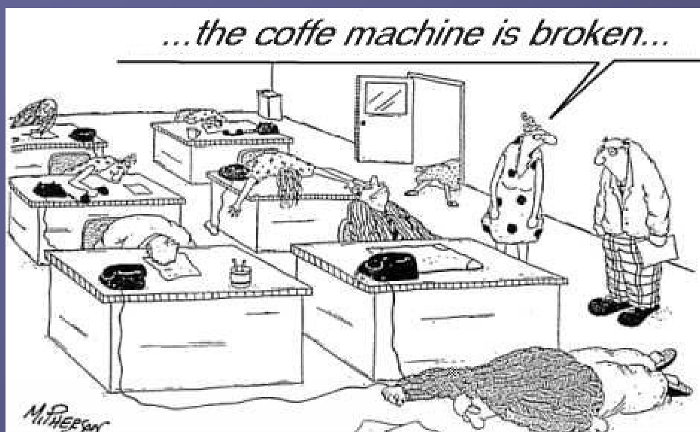
NIOSH is also investigating other direct reading devices for diesel



e.g. PDM was used as

- Tailpipe monitor
- Engineering tool for coal mines

Questions


...the coffe machine is broken...
McPHERSON


Snapshots at jasonlove.com
GROCERIES
POST OFFICE
GASOLINE

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WORKSHOP

Ergonomics

Day 1 – continued — Ergonomics and Vibration

Session 3: Ergonomics and Vibration
Monitors: Brian Lowe (NIOSH), Rob Radwin (University of Wisconsin-Madison)
Speaker/Title of Presentation:

1. Brian Lowe/Rob Radwin – Overview of session
2. Raymond W. McGorry (Liberty Mutual Research Institute for Safety) - Examples of DRM applied for Musculoskeletal Disorder and MSD risk factor exposure assessment

Rapporteur: Vern Anderson (NIOSH)
Topics of discussion:

1. The unique challenges of ergonomic hazards for DRM
2. A working definition of DRM for ergonomics/MSDs (mechanical load on musculoskeletal system)
3. The importance of DRM for MSD exposure assessment
4. The advantages/disadvantages of existing instrumentation-based methods.
5. Specific NIOSH National Occupational Research Agenda (NORA) sector needs

2008 NIOSH DREAM Workshop

Session 3: Ergonomics and Vibration

Direct measurement of force exposure in hand tool use

Ray McGorry
Liberty Mutual Research Institute for Safety
Hopkinton, MA

November 13-14, 2008
Washington, DC

Workshop Goals

"Develop practical and consistent methods for objectively measuring physical stress….and for quantifying occupational exposure…."

"… to understand the quantitative exposure or dose-response relationships between

(1) exposure to external loads in the workplace and the resultant three-dimensional internal loads and physiological responses and

(2) exposure to external loads in the workplace and pain, discomfort, impairment, and disability. …"

Exposure to external loading

Survey of Ergonomists (CPEs)

- Observation / Subjective ratings
  - Frequent use
  - Video, checklists, tools (RULA, HAL)
- Psychophysical estimates
  - Occasional use
  - Hand and pinch grip dynamometers
- Direct measures
  - Infrequent use – due to expense, availability, lack of expertise (scales, push pull gauges were more commonly used - where applicable)

Dempsey et al. Applied Ergonomics, 2005; 36:489-503

LMRIS Direct reading program

Force exposure measurement with single-handled tools

- Many hand tool tasks are associated with repetitive strain injuries
- Exposure is difficult to measure
- Goal - measure grip force and applied moments during hand tool use, in the field and in the lab

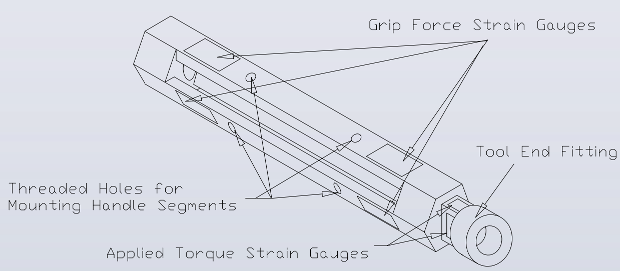
Design of measurement system

- Design constraints
  - Preserve original characteristics of the tool handle and end effector
  - "Universality"
  - Size, weight, cabling, handle configuration
  - Number of sensors
  - Durability
  - Fabrication and cost
- Several generations of designs

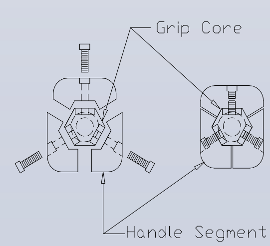
McGorry RW. Applied Ergonomics. 2001;32:271-279.

Design concept

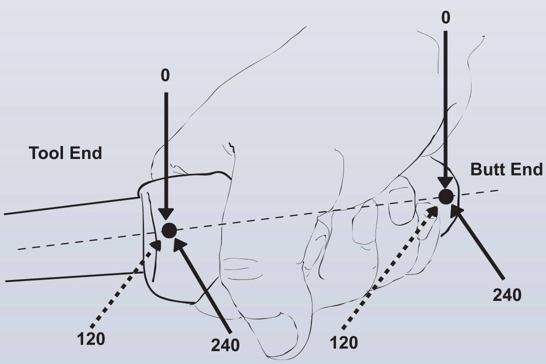
Perspective View

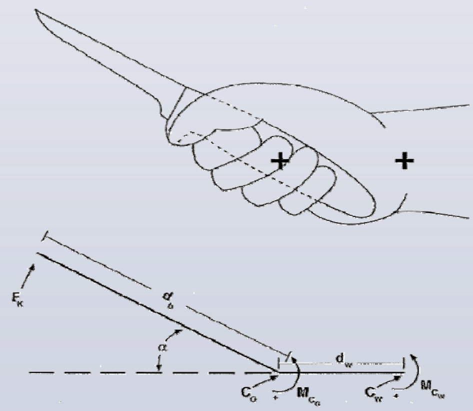


End View - Cut Away



Design concept



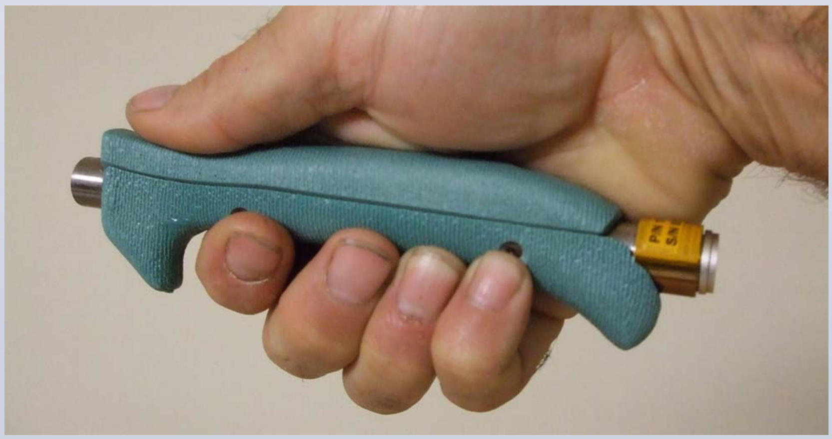


Current design

- Titanium core – 12.5 mm diameter
- Grip force – 3 suspended beams, strain gauges at both ends
- Moment (x and y) and axial torque at tool end

Current design

- Female mold of tool handle made in silicon
- Polyurethane casting material, poured around instrumented core blank
- Casting split into three parts

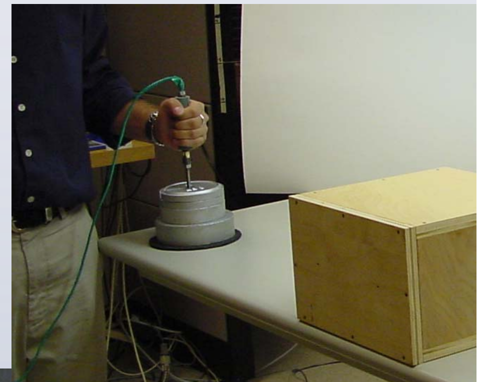


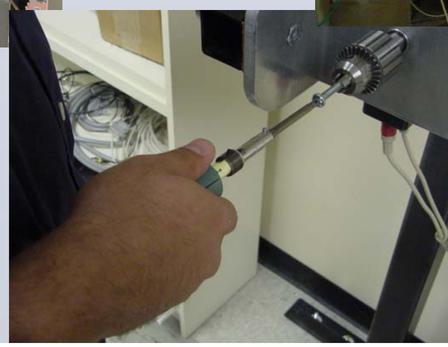
Current design

- Tool end effector welded to threaded stud
- Cable connected to transmitter

Psychophysical estimates

How well do people estimate grip force when using hand tools?





Psychophysical estimates

Results

- Large individual variability in estimates
- More accurate estimates of mean force than peak force
- Dependent on how force is applied

Casey et al., Prof Safety, 2002;47:18-24

McGorry et al., J Occup Rehab, 2004; 14:255-266

Psychophysical estimates

Individual variation in psychophysical estimate of grip force

% Estimation Error

Subject	Mean Grip Force	Peak Grip Force
1	79.9	3.6
2	65.0	11.3
3	39.8	-16.3
4	-51.9	-71.1
5	7.6	-40.1
6	4.8	-40.2
7	25.2	-34.3
8	-52.9	-74.2
9	-48.2	-70.4
10	-32.6	-62.2
11	7.0	-38.8
12	-28.8	-62.2
13	-3.3	-48.0
14	-4.0	-46.3
15	-38.8	-64.2
16	-46.3	-72.9
Mean (s.d.)	**-4.8 (41.5)**	**-45.4 (26.3)**

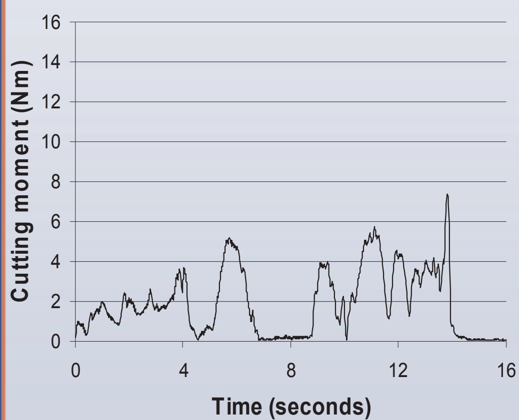
Percent estimation error = (actual grip force - estimate) / actual grip force, expressed as a percentage. A negative value represents an underestimation.

Casey et al., Prof Safety, 2002;47:18-24

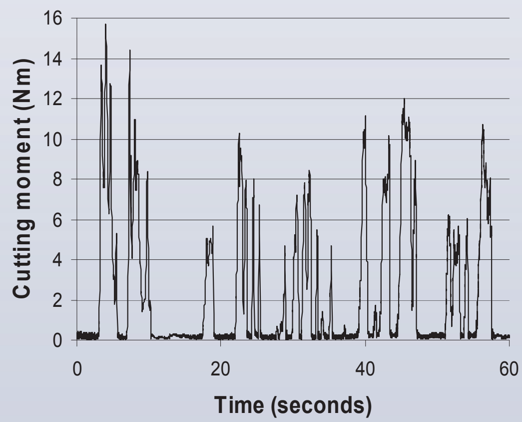
Field studies – meat cutting

Field studies – meat cutting

Two operations – two patterns of force application



Lamb Y-cut

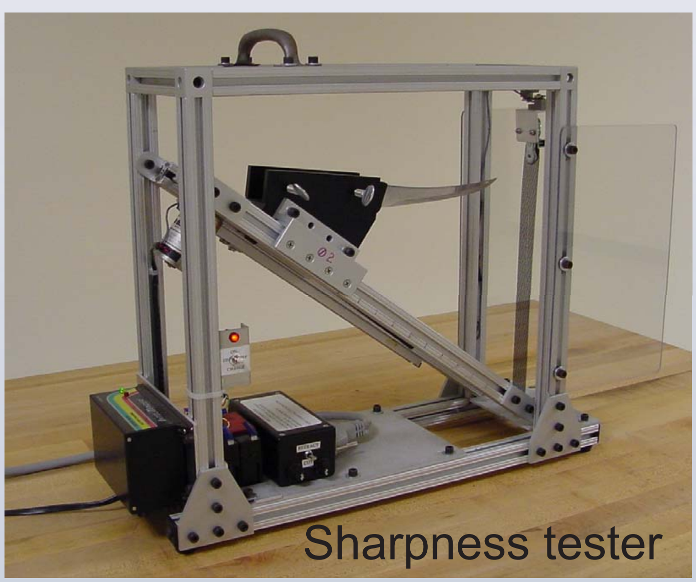


Lamb shoulder fleecing

McGorry et al., Applied Ergonomics. 2005;36:71-77

Field studies – meat cutting

Effect of blade sharpness



McGorry et al., Applied Ergonomics. 2003;34:375-382

Field studies – meat cutting

Effect of blade sharpness

	Grip Force (%MVC)		Cut Moment (%MVC)	
	Average	Peak	Average	Peak
Operation				
Shoulder	27.2 (11.9)	85.8 (32.0)	35.9 (10.9)	130.7 (32.0)
Rib	32.0 (12.7)	66.8 (20.9)	28.3 (8.9)	109.8 (23.9)
Loin	24.8 (4.4)	60.3 (20.3)	23.1 (3.9)	104.1 (17.7)
Sharpness				
Sharp	25.5 (10.2)	64.9 (27.9)	25.9 (9.2)	101.8 (24.9)
Dull	29.8 (12.1)	76.9 (31.4)	31.4 (9.7)	127.4 (29.0)

Blade dulled by one pass through 400 grit sandpaper.

McGorry et al., Applied Ergonomics. 2003;34:375-382

Field studies – meat cutting

Effect of blade sharpness

Mean differences and percent change due to blade sharpness

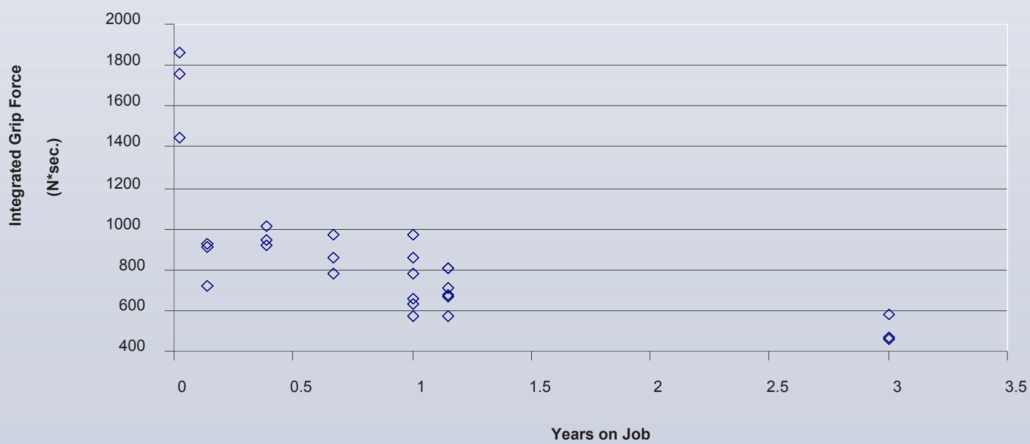
Dull vs. Sharp Blade	Mean (s.d.)	% Change	*p*
Sharpness score (N)	3.5	25	**< 0.0001**
Cutting Time (sec)	4.8 (6.4)	37	**0.012**
Peak Cutting Moment (Nm)	3.3 (2.9)	30	**0.001**
Mean Cutting Moment (Nm)	0.9 (0.9)	33	**0.014**
Peak Grip Force (N)	17.2 (38.9)	24	0.116
Mean Grip Force (N)	6.1 (9.9)	21	**0.038**

Blade dulled by one pass through 400 grit sandpaper.
*Significant results indicated in **bold** text.*

McGorry et al., Applied Ergonomics. 2003;34:375-382.

Field studies – meat cutting

Effect of experience



Dempsey and McGorry, J Occ Env Hyg, 2004, 1;167-172

Lab studies – pneumatic nutrunner

ISO 6544

Hand-held pneumatic assembly tools

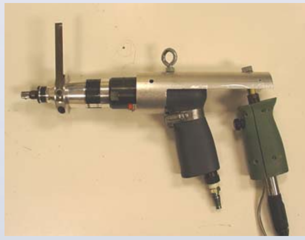
for installing threaded fasteners –

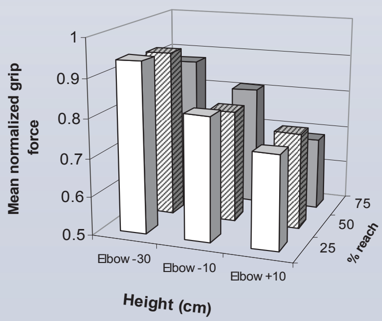
Reaction torque and torque impulse measurements

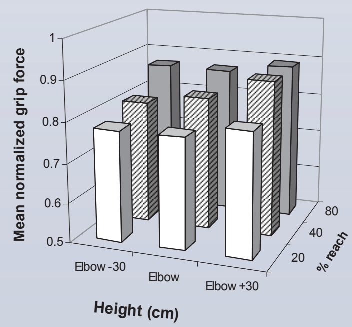
- *"Nor are there at the time of writing this International Standard, any known devices for measuring torque and force that can be used between the tool and the operator."*
- Lin, J-H, McGorry RW, 2007. Hand-handle interface force and torque measurement system for pneumatic assembly tool operations: a supplement to ISO 6544. Journal of Occupational and Environmental Hygiene, 4, 332-340.

Lab studies – pneumatic nutrunner

Grip force vs. work orientation and position







McGorry and Lin. Ergonomics, 50, 1392-1403, 2007

Lab study - simulated meat cutting

Work station and task variables

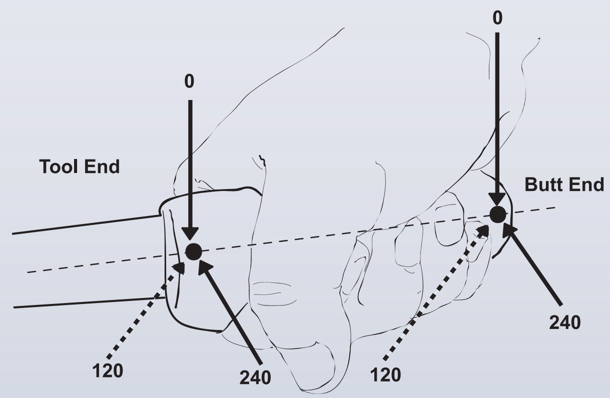
McGorry et al., Ergonomics, 2004; 47:1640-1656

"Efficiency" of force application

Mean cutting moment and grip force for a lab simulation (pacing) and two meat cutting operations

	Mean Cut Moment (Nm)	Mean Grip Force (N)	Grip to Cut Ratio
Task Pace			
Self	5.8 (1.2)	46.6 (14.4)	**8.0**
Production	6.8 (1.4)	58.9 (14.6)	**8.7**
Meat packing			
Shoulder cut	4.7 (1.1)	41.6 (10.8)	**8.8**
Loin trim	2.3 (0.4)	31.2 (3.9)	**13.6**

Distribution of forces



Peak force distribution (% of total) across six sensors

	0 Tool	0 Butt	120 Tool	120 Butt	240 Tool	240 Butt
Simulated cutting (lab)	62.1	2.3	0.0	11.7	6.1	17.8
Meat cutting (packing plant)	64.4	8.9	0.0	8.9	0.0	17.8
Ratchet	0.0	35.9	20.3	7.8	25.0	10.9
Screwdriver	1.0	25.7	8.4	29.8	7.3	27.8

Laboratory studies

- Pneumatic nutrunners
  - Lin et al., Ergonomics. 50, 859-876, 2007
  - Lin and McGorry. J Occup Envir Hygiene, 4, 332-340, 2007
  - McGorry and Lin. Ergonomics, 50, 1392-1403, 2007
- Ice cream scooping
  - Dempsey et al., Applied Ergonomics, 2000;31:121-130
- Screwdriver, ratcheting
  - McGorry et al., J Occup Rehab, 2004; 14:255-266

Present work

- ACGIH TLV – Hand Activity Level
  - Uses expert rating of task demand, Borg Scale (0 -10) or psychophysical estimate
  - Initial report - comparison of direct measure to Borg scale and psychophysical estimates - 16 subjects, multiple tasks
- NIRS and tissue perfusion in the upper extremities

Future work

- Collaboration with GTRI - poultry processing plants in southeastern USA
  - Determine exposure levels
  - Examine safety margin
  - Investigate training, job rotation as potential interventions
  - Evaluate intervention

Where do we go from here?

- What are your thoughts on future technological approaches, what exposures to assess, etc.?

Noise

Day 1 – continued Noise

Session 4: Noise

Aim: The broad aim of this session is to seek stakeholder input in shaping a NIOSH research agenda for DRM as related to noise exposure in the workplace.

Monitors: Chuck Kardous (NIOSH) and Rob Brauch (Larson-Davis, AIHA)
Rapporteur:

Speaker/Title of Presentation:

1. Chucri A. Kardous (NIOSH) – Introduction And Brief Overview Of NIOSH Research
2. Robert Brauch (Larson-Davis, AIHA) – Current Instrumentation And Future Developments
3. John J. Earshen (Angevine Consultants, AIHA) – Noise Exposure Metrics
4. John P. Seiler (MSHA) – A Historical Perspective On The Evaluation, Standardization And Certification Of Personal Noise Dosimeters
5. G. Richard Price (Auditory Hazard Analysis) – Physiological Basis For Time-Domain Direct-Reading Noise Hazard Assessment

Topics of discussion:

1. Establish a working definition of DRM for Noise
2. Mixed or combined exposures
3. Impulse/Impact noise DRM
4. Worker empowerment
5. Need for the testing, evaluation and certification of DRMs in the US
6. Environmental factors in the use of DRMs
7. Need for guidance/standard methodologies for use of DRMs
8. Data management challenges
9. Training and education

Direct-Reading Noise Exposure Assessment Methods:
Noise Exposure Instrumentation

From the Present – to the Future

Robert G. Brauch

Industrial Hygiene Product Manager

Larson Davis, a division of PCB Piezotronics, Inc.

2008 NIOSH Direct-Reading Exposure Assessment Methods (DREAM) Workshop

November 13 - 14, 2008 ◆ Hilton Crystal City in Washington, D.C.

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CDC

NIOSH

A Manufacturer's Perspective

- Current Dosimeters - in transition
  - Form factor vs. functionality
- Effects of Technology development
  - Advances and limitations – 'along for the ride'
- Role of Dosimeters - today and tomorrow
  - Compliance vs. best practice
- Drivers of Dosimeter Development
- What will dosimeters be like in 2020?

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Current / Future Noise Dosimeter Development Trends

- Smaller size, lighter weight
- Integrated Form Factor – shoulder mountable
- Infra-red, RF, other remote readout technologies
- Continual interrogation of data and continuous monitoring of exposures – remotely
  - Central 'command'?
- Frequency Analysis (Octave Band)
- Stereo measurement (left side / right side)
- Monitoring inside the ear-canal
  - What does the data mean?
- How much data is *too much* data?

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From the Present to the Future

- 'Traditional' Dosimeters have a long evolutionary history – 2 main events:
  - Microprocessors and Digital Storage (1970's)
    - Time History and detailed statistical histograms
    - Major step forward in documenting exposure
  - Advent of the PC (1981)
    - Ability to store, manage, view and print
- Led to large increases of data acquisition with additional complexity and non-essential metrics (L_{DN}, etc.)

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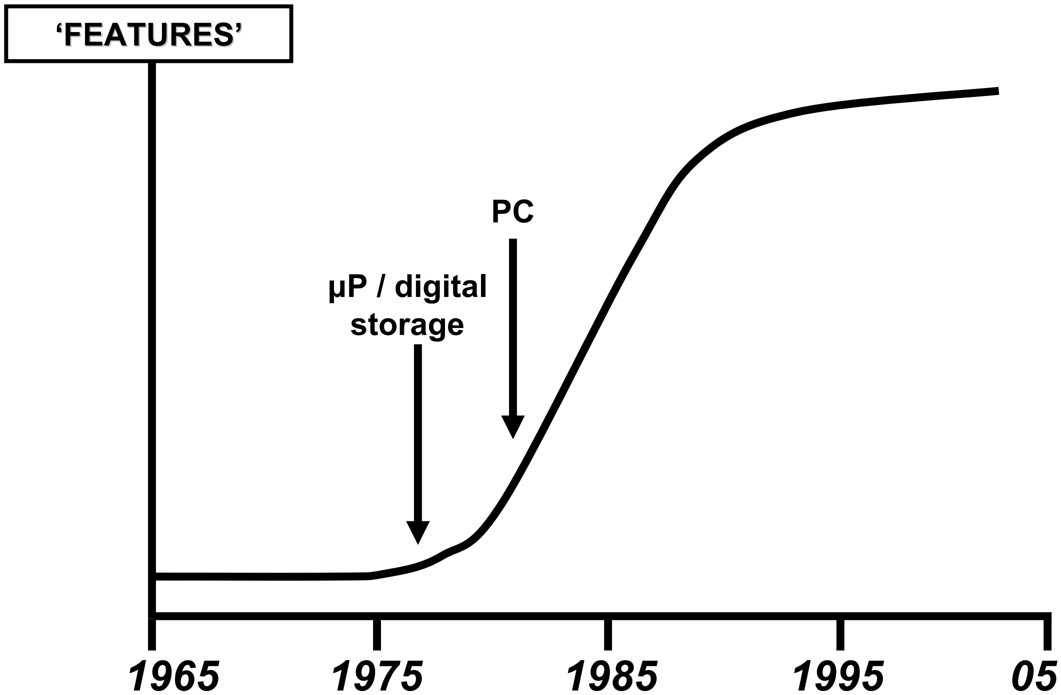
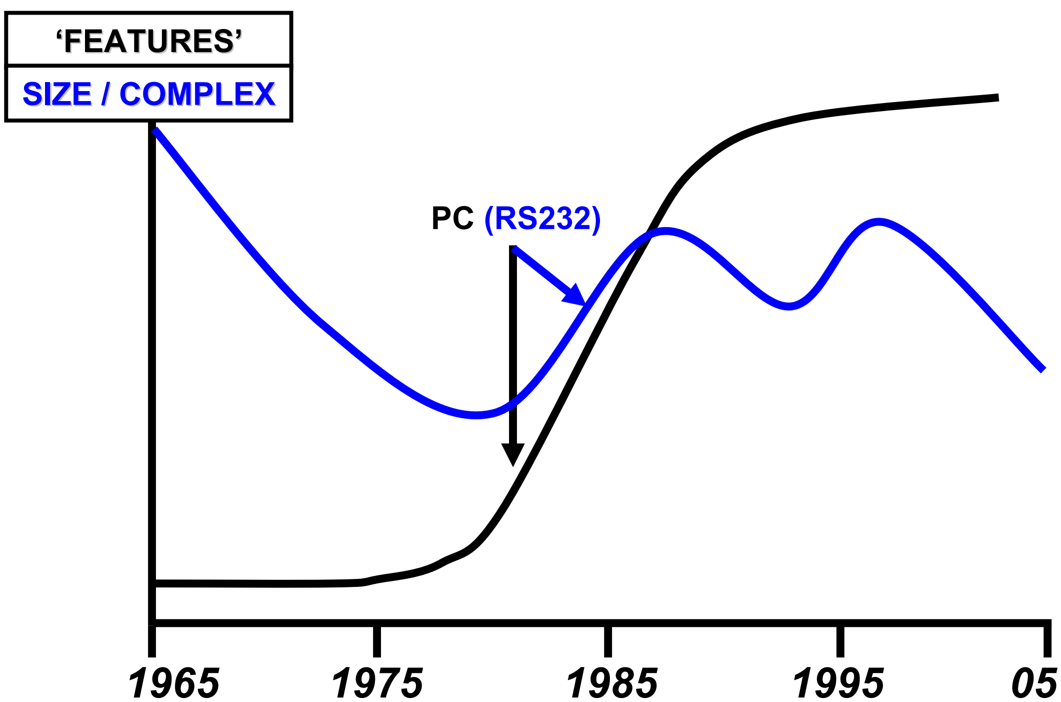
Historical Trends



Historical Trends



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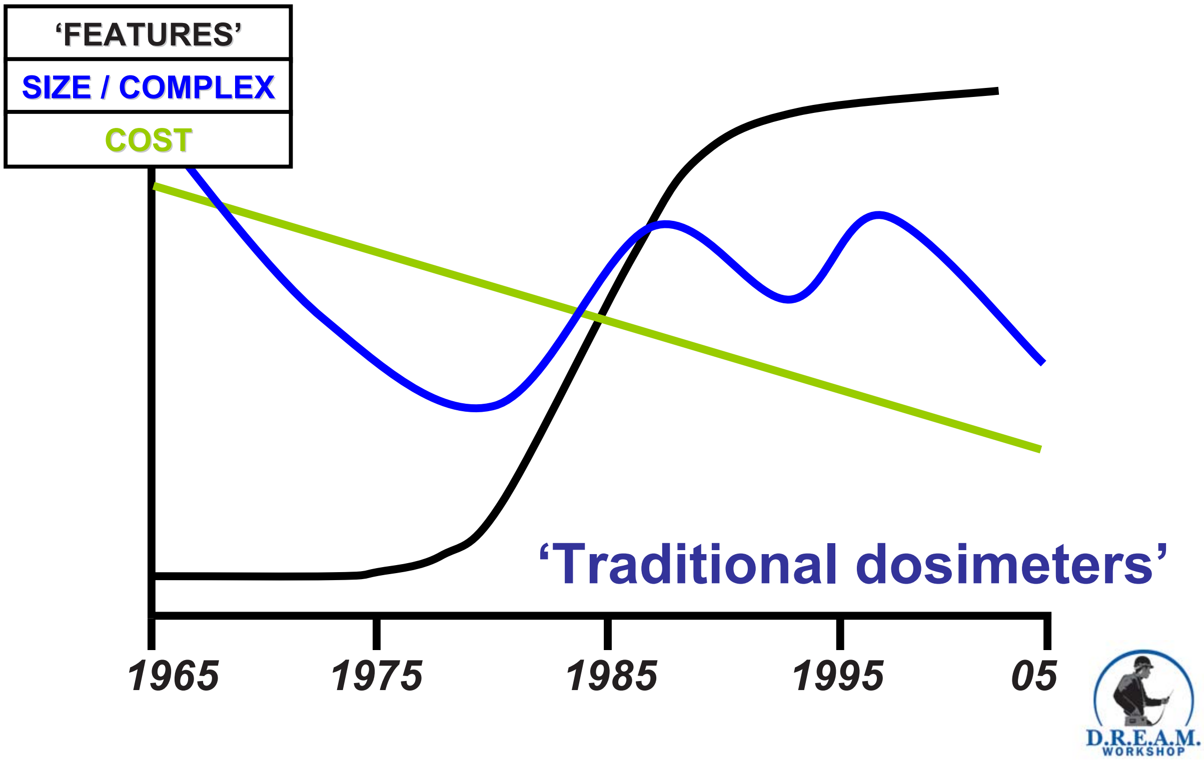
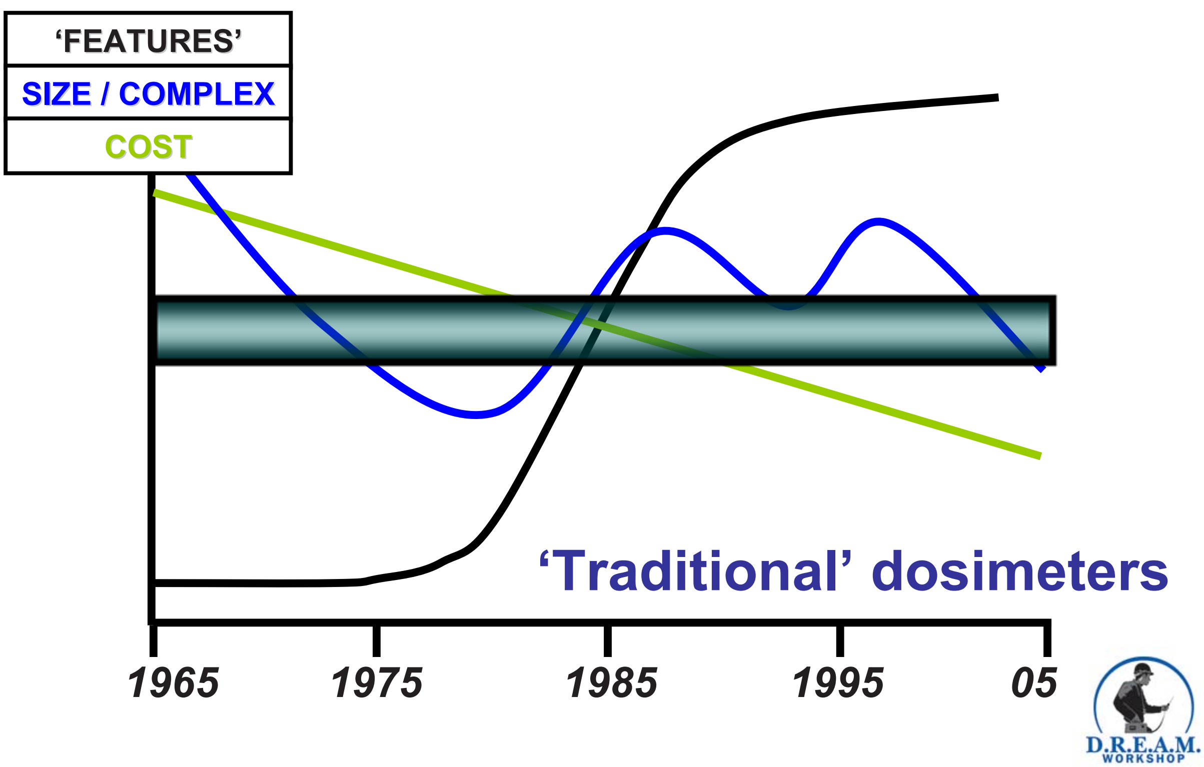
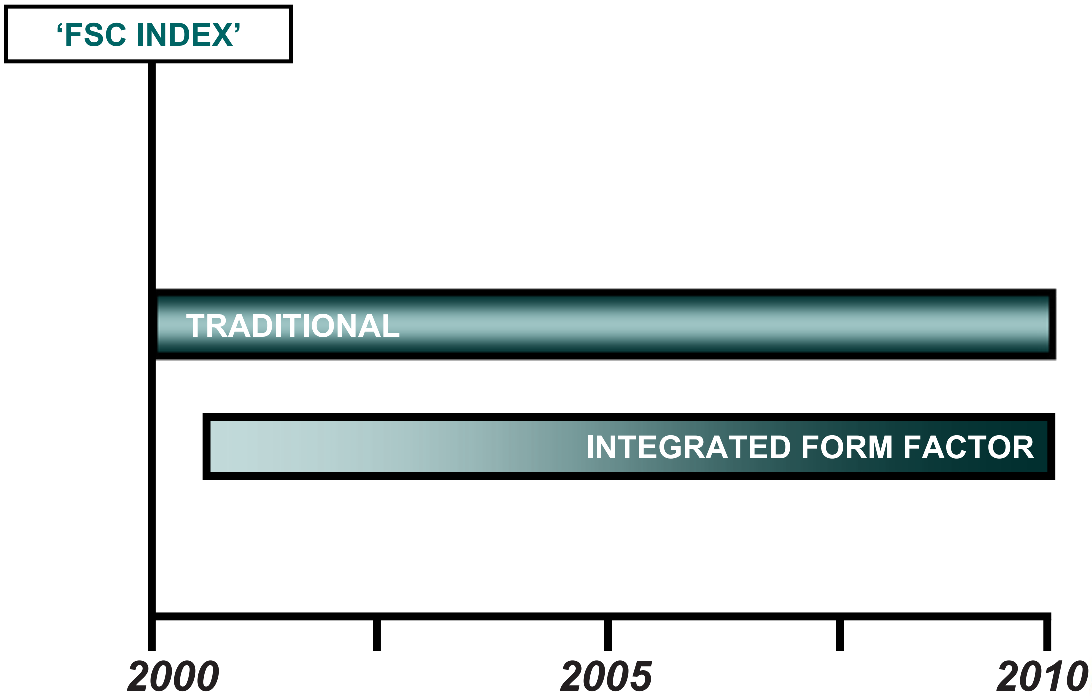


Historical Trends

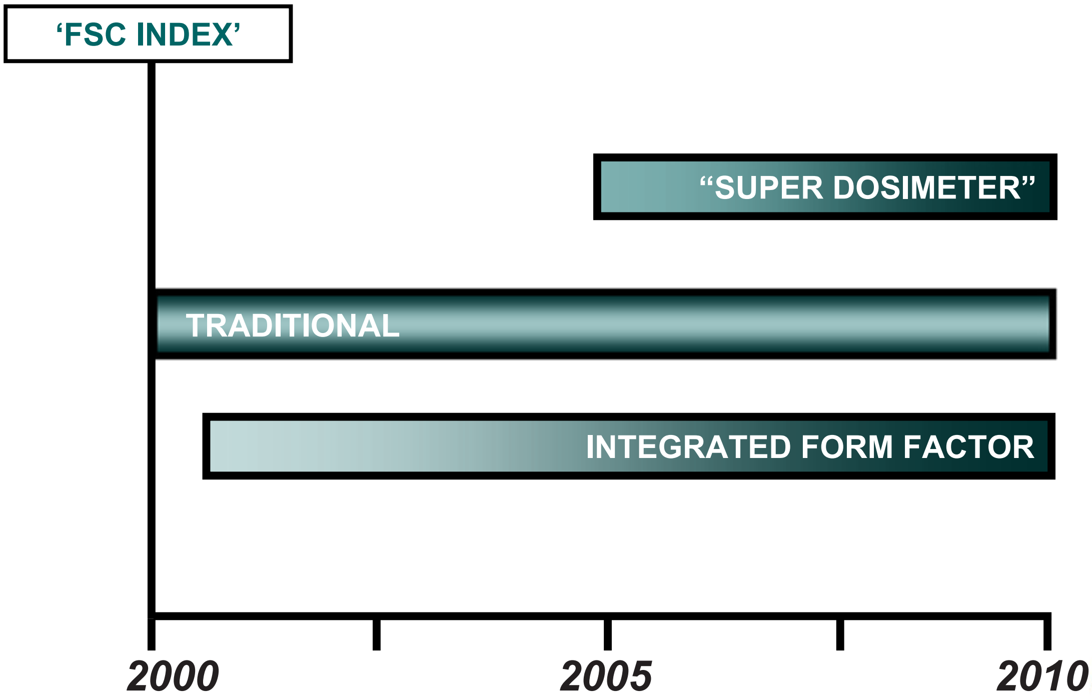


Emerging Trends



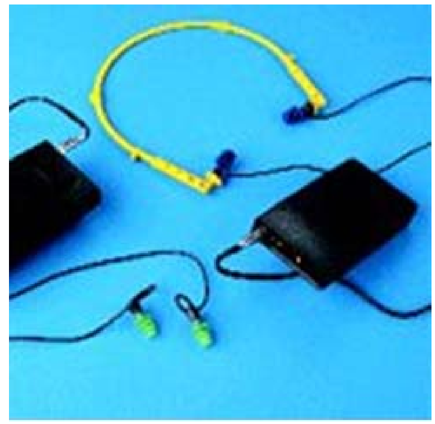
Integrated Form Factor

Emerging Trends

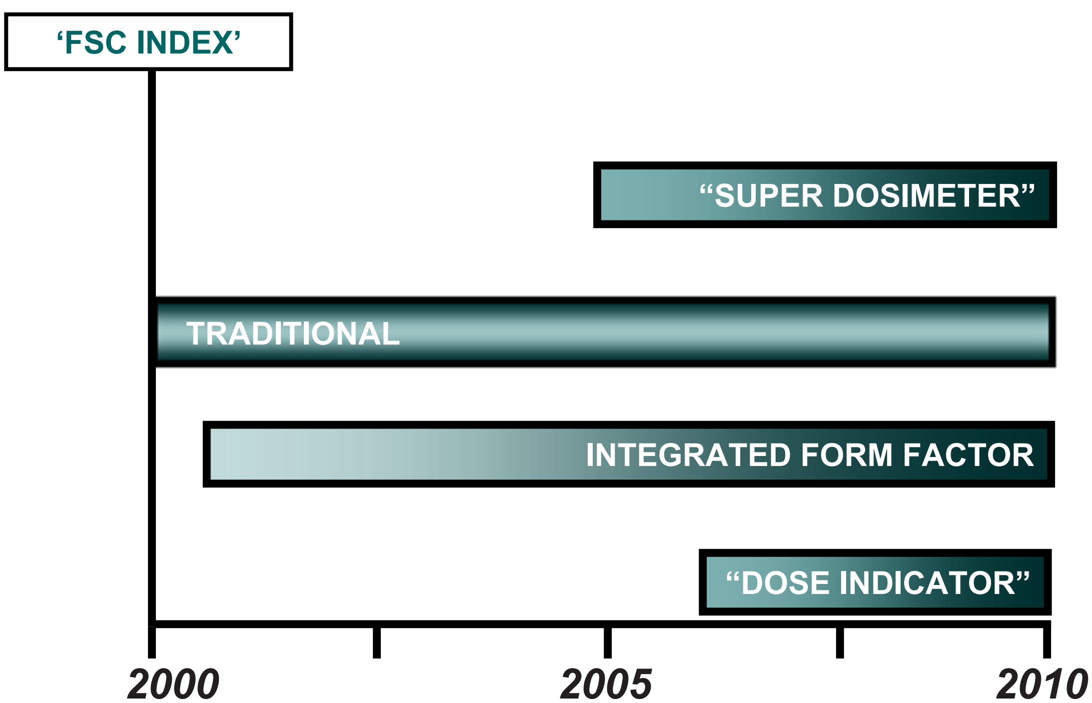


New Dosimeter Types

New Dosimeter Types

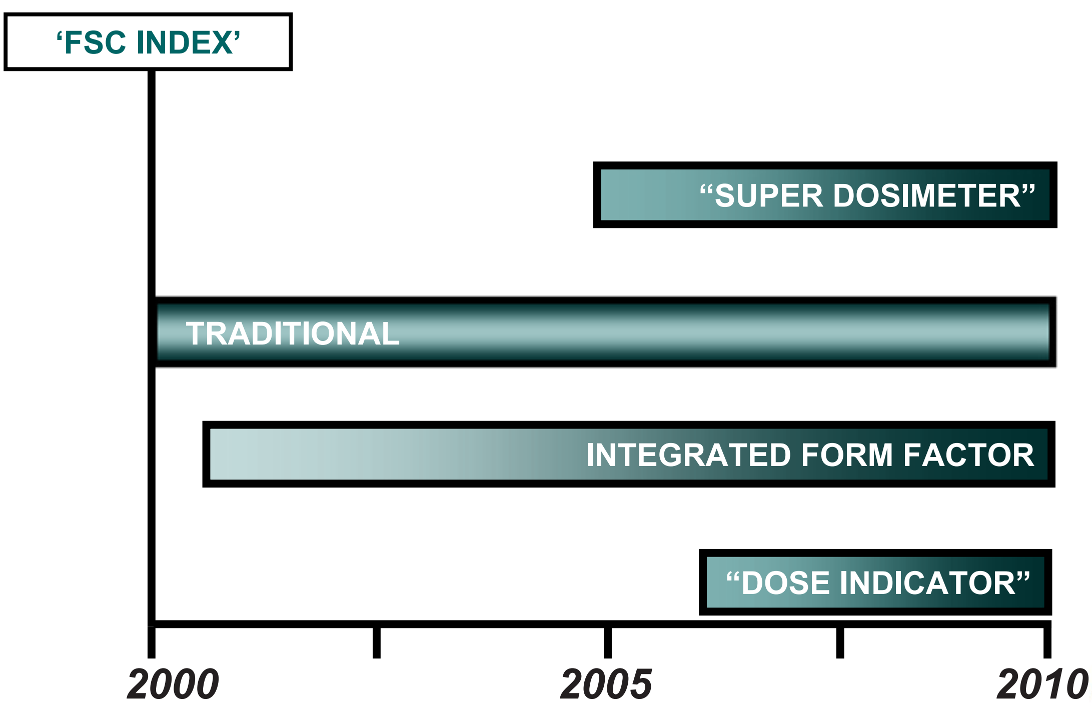


Emerging Trends

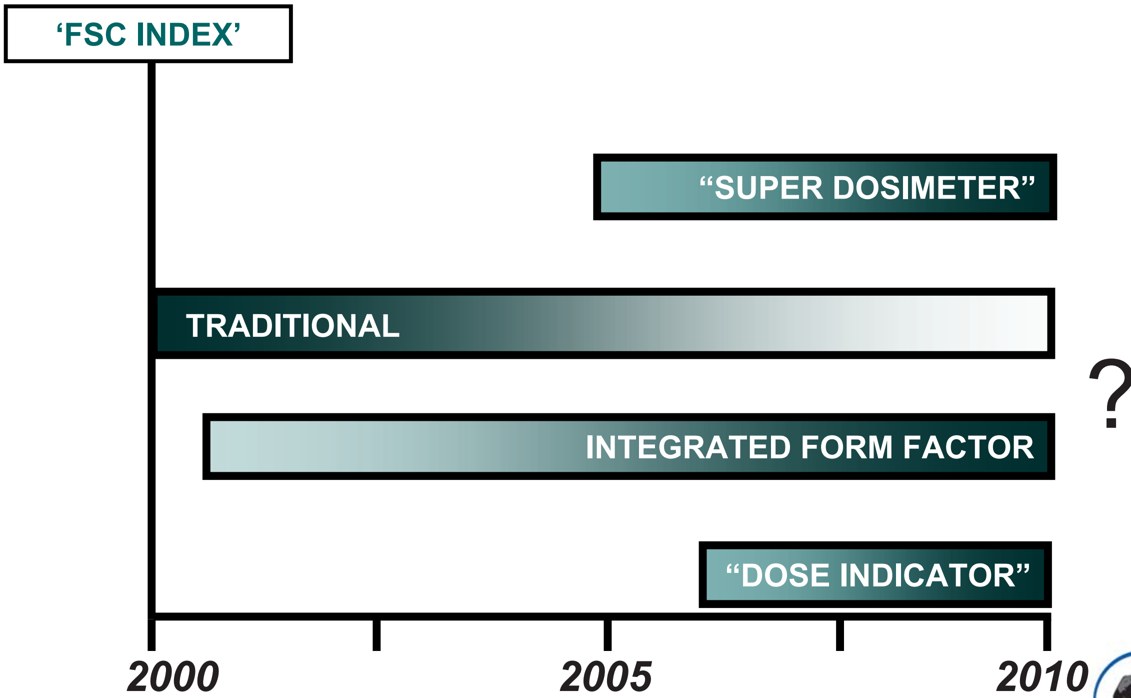


SPL and Noise Dose Indicators

Emerging Trends



Emerging Trends



Dosimeters *could* be...

- More simple and ubiquitous
  - Inexpensive screening tools (non-conforming)
  - Basic compliance tools
- More powerful and accurate
  - Taking advantage of high-speed Digital sampling
  - Incorporating new measurement criteria
- Multifunctional
  - e.g., Incorporating environmental and behavioral input

Development Drivers: + and -

- Technology availability
  - – Driven by consumer goods: Phones, PC, etc.
    - Example: Digital Storage vs. Digital Sampling
- New Research – new metrics
- Customer Input
- Regulatory Pressure or lack thereof
- Economic Incentive / lack thereof
- Market Size
- Investment Viability

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Market conditions

- Dosimeter market today is largely a ‘replacement market’ in the US
- Overall demand has fallen or remained static
  - – Decreased industrialization, success of ‘buy quiet’ programs
  - – Downsizing increases pressure on Health & Safety professionals to ‘do more with less’
- Other markets outside US require different features / results / performance criteria

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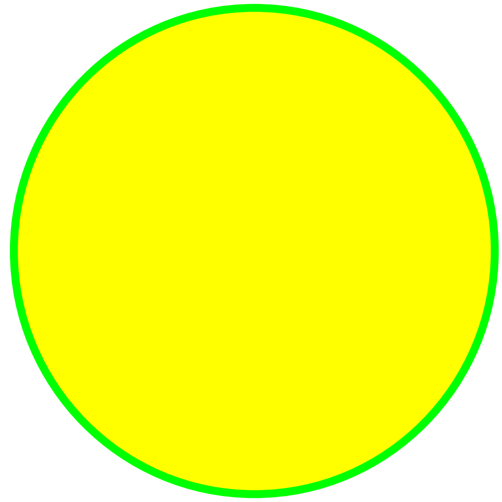
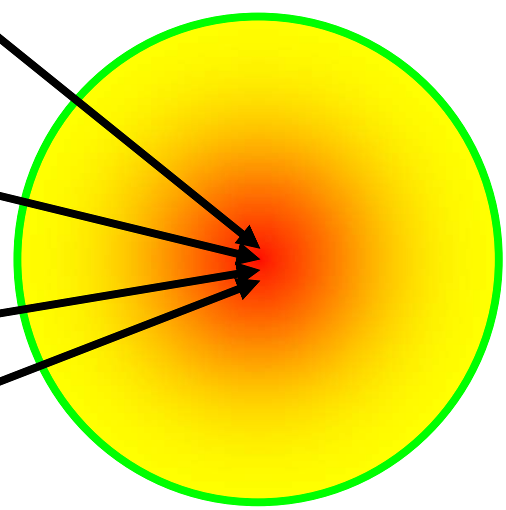
New Device Catalysts

- Technology availability
- ‘Practicability’
- Regulatory pressure
- New Metrics



New Device Catalysts

- Technology availability
- ‘Practicability’
- Regulatory pressure
- New Metrics



Dosimeter Technology Issues

- Detectors (A to D or just D)
- Microprocessor speed (power)
- Memory
  - File size/download times, Data retention
- Digital sampling – how fast is fast enough?
- Microphone
  - Performance, Cost, Survivability
- Battery
  - Operating costs, Lifespan, Availability
- Intrinsic Safety Requirements

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Blue sky...?

- New measuring and analysis capabilities
  - Increased accuracy / response
  - Advanced analysis algorithms
    - New DRC model?
- Integration of noise dosimeter into other devices
- In ear measurement with integrated form factor, i.e. wireless

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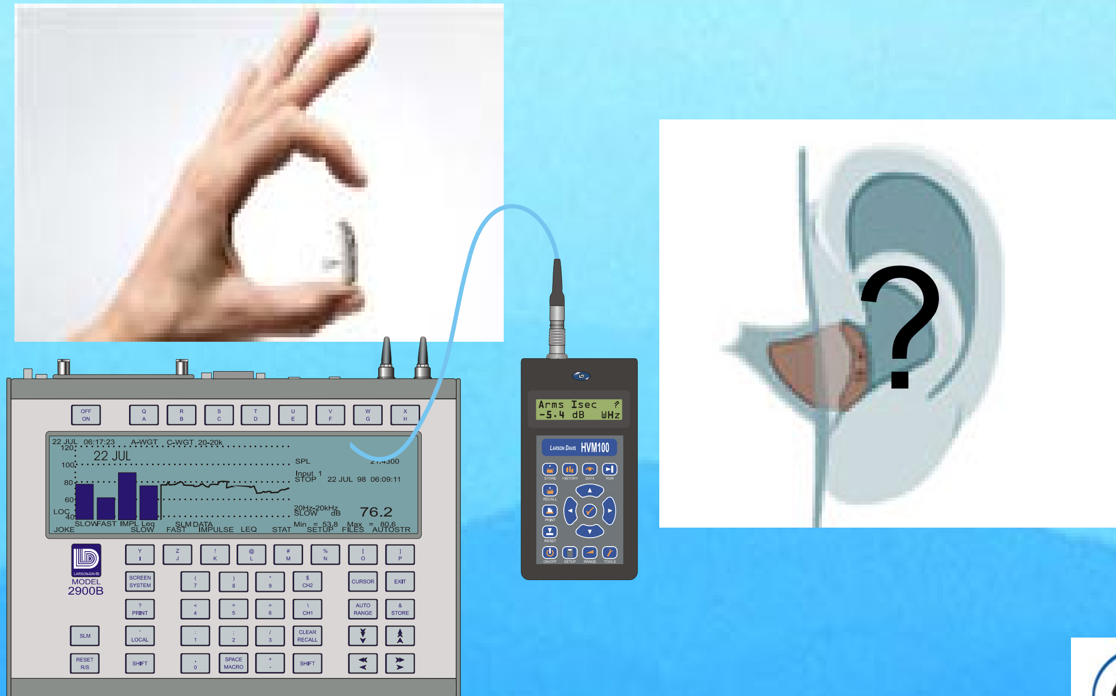
In the (y)ear 2020?



We want to hear from you

Manufacturers want to provide new and better solutions in response to market needs!

Conclusions

- Fundamental technologies allowing for various new classes of dosimeters are available today
- Demand is driven by US market conditions and international requirements
- Market demand ultimately drives investment in product development – standard business model
- Manufacturers provide only the ‘D’ in R&D
- Dosimeters can and should play a more integrated, powerful and decisive role in Hearing Conservation practices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Noise Exposure Metrics
(Established and Potential)
For DREAM workshop discussion

John J. Earshen, M.S., F. ASA
Principal, Angevine Acoustical Consultants, Inc.

INTRODUCTION

- To stimulate discussion of candidate direct-reading exposure assessment methods, salient metrics applied in regulatory and professional practices are reviewed.

- The metrics quantify damage risks to hearing resulting from cumulative exposures to noise.

Outline

ULTIMATE OBJECTIVE FOR DRMs:

FACILITATE PROTECTION AGAINST DAMAGE TO HEARING BY EXPOSURE TO NOISE

DRMs :

FACILITATE DETECTION OF HAZARDS
PROVIDE GUIDELINES FOR REGULATING AND ENFORCING LIMITS ON EXPOSURE

Outline

STATUS OF KNOWN DAMAGE HAZARDS

ONLY EMPIRICAL DATA RELATES PROPERTIES OF DAMAGING NOISE TO TTS AND PTS

EVALUATION OF HAZARD RISKS IN MANY AREAS ONLY FEASIBLE AFTER THE FACT

ANALYTIC MODELS-UNDER DEVELOPMENT

DESIRED END RESULTS:

CAPABILITY OF PROVIDING REAL TIME PRESENTATION OF HAZARD
GENERATING EXPLICIT FUNCTIONAL SPECIFICATIONS FOR MONITORING INSTRUMENTS

REFERENCED METRICS

▪ Metrics are empirically related to observed exposure effects on Temporary and Permanent Threshold Shifts.

[PTS and TTS]

▪ Properties of sound considered are limited to pressure, frequency content, and waveforms (energy transfers and true intensities are not addressed).

▪ Over the entire perceivable range of hearing damage effects start upward from approximately 75 dBA.

RELATIONS of METRICS to INSTRUMENTS

▪ Historically, terms incorporated in metrics have been derived from uses with Sound Level Meters and Audiometers.

▪ There is nothing intrinsic requiring use of decibel notation

▪ Adoption of terms applicable to analytic physical laws can be misleading and tend to obscure the empirical nature of what is known about hearing damage by sound exposure. (e.g. reference to equal energy properties).

NOISE DOSE CONCEPT

- References a maximum criterion level (in decibels) to which unprotected exposure is permissible for a typical shift duration.
- Reduction of exposure duration permits an increase in level;
- Increase in exposure duration requires a decrease in level
- The increase or decrease in level related to halving or doubling of duration is designated the exchange rate.
- In OSHA practice the exchange rate is 5 dB
- The dose is stated in percent by normalizing with respect to the combination of criterion level and reference shift length.

APPLICATIONS of NOISE DOSE

- Values of Criterion Level and Exchange Rate are not universally used.

- Criterion levels and exchange rates selected by different regulatory agencies include respectively [84, 85, 90 dBA] and [3, 4, 5, and 6 dB]

- “Equal Energy” concept utilizes only a 3 dB exchange rate.

IMPULSE / IMPACT EFFECTS

- It is known that transient sounds of short duration and high amplitudes have a different and more damaging effect on hearing in comparison to a slowly varying or steady sound having an average value equal to the transient sound.

- Nevertheless, the dose based metric used in many applications incorporates contributions from the transient components on an equal basis to contributions from slowly varying waveforms.

COUNTING IMPULSIVE TRANSIENTS

- Other attempts to differentiate the effects of short duration transients set up tables of impulse amplitudes in increments. For each increment exposure to permissible number of impulses was defined.

- The approach suffered from inability to accommodate transients of varying waveforms as well as development of an instrument that could compute and store exposure data on a real time basis.

CREST FACTOR DIFFERENTIATION

▪ Passhier-Vermeer, Henderson, Bruel, and others developed a method whereby exposure to sound waveforms having equal average levels were compared. Each was characterized by a crest factor. The waveforms with the higher crest factors were shown to produce significantly higher threshold shifts.

KURTOSIS

▪ Hamernick devised a metric for differentiating the impact on threshold shift based on the kurtosis properties of exposure waveforms having equal Leq levels. The approach has been extensively investigated in animal studies.

▪ Recently a successful pilot study demonstrated differential impact by high Kurtosis noise on threshold shifts of workers in two plants in Montreal, Quebec. The high kurtosis noise is contained in a sheet metal fabrication plant. In contrast low kurtosis noise of equal Leq level is in a plastic component manufacturing plant.

▪The investigation was conducted by Marie Champagne, a doctoral candidate at the State University of New York at Buffalo with collaboration by Hamernik, Henderson, and Bertrand.

SUMMARY

Review of metrics based on empirically derived relations between cumulative exposures to sound pressures having unique frequency contents and waveforms can stimulate development of direct-reading exposure assessment methods and formulate performance requirements for monitoring instruments.


D.R.E.A.M.
WORKSHOP

A Historical Perspective on the Evaluation, Standardization and Certification of Personal Noise Dosimeters

JOHN P. SEILER, P.E., F. ASA
Chief, Physical and Toxic Agents Division
USDOL – MSHA
Pittsburgh, PA

Today's Presentation

- Noise Dosimeter Development – Historical
  - Original Concept and Generations 1, 2, 3, & 4
- Evaluation of Noise Dosimeter Performance
  - Laboratory and Field
- Standards
  - ANSI
- Testing and Certification
  - NIOSH/MSHA

Noise Dosimeter Development

- 1954, AIHA – Rosenwinkel & Stewart – described a ”new device which integrates sound energy over finite time periods.”
- 1955 – Stewart patent (assigned to MSA 1961) an instrument that would “sum the sound energy in the environment in such a way that the total variables of frequency, intensity and time would be accumulated together in a manner similar to the way the ear hears them.”

Noise Dosimeter Development

- 1956 – von Wittern and Von Gierke patent for a noise exposure meter for ‘indicating the total time that noise exceeded a certain predetermined levels.”
  - Measurements could be conducted over long periods of time, and the instrument worn by personnel under normal work conditions
- 1957 - Crouch, AIHA, ‘instrument that described the time the noise level was above a series of five adjustable sound pressure levels.”

Noise Dosimeter Development

- 1964 USAF – indicated an interest in developing a personal noise dosimeter that was light weight, pocket sized and provide a measure of average noise exposure during a normal working day.
  - Texas Research Associates prototype.
- 1965 – Church described a small personal instrument to record amount of time worker is above a selected level.
  - 3 trigger levels

Noise Dosimeter Development

- 1966 – Lagerholm and Toremalm described a dosimeter which had an adjustable tolerance level from 70 – 100 dB. A motor accelerated with increasing noise intensity above a preselected level in such a way that the registered value was a product of duration and intensity.
- 1970 – Botsford and Laks described a noise hazard meter to be worn by a roving workman that permitted evaluation of many exposures to irregular noise that were unassessable by then present methods.

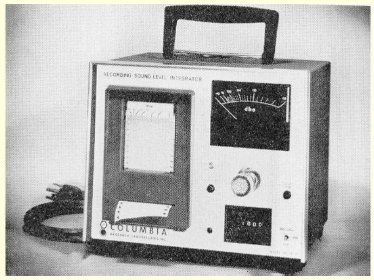
Noise Dosimeter Development

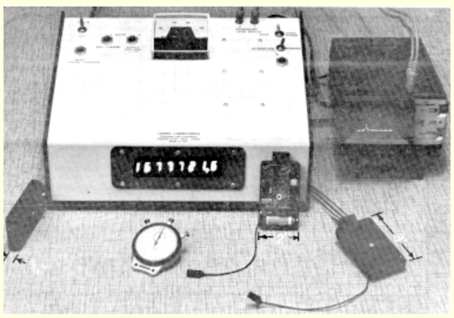
- The 1969 Coal Mine Safety and Health Act and the1970 Occupational Safety and Health Act spurred the development of portable and person-worn instruments for the measurement of occupational noise exposure.

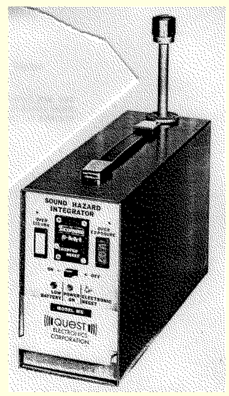
Noise Dosimeter Development Generation 1

- Pre-commercial and early commercial
- 1960-1971
- Portable or person-worn (unwieldy)
- Quest M-5 Sound Hazard Integrator, Columbia Research SPL 101, GenRad 1934
- Usually had 1-1/8” Diameter microphone, LED or mechanical readouts
- High battery drain which limited operating time and portability

Generation 1



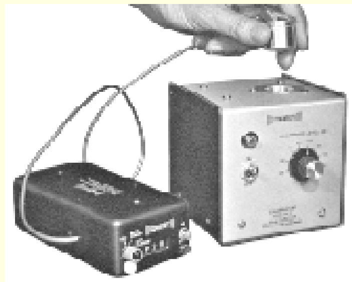


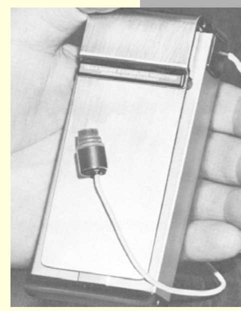


Noise Dosimeter Development Generation 2

- 1972-1980
- Until the first ANSI Noise Dosimeter Standard
- Either separate monitor-readout or self-contained
- Single function instrument, 1-inch dia. Microphone (integral or remote) & LED display
- Limited in dynamic range, frequency response, and crest factor capability.
- Single Threshold, weighting, and exchange rate.
- DuPont Model A, D-100, D-285, D-376, B&K 4425, Quest M-6 and M-7, GenRad 1944

Generation 2





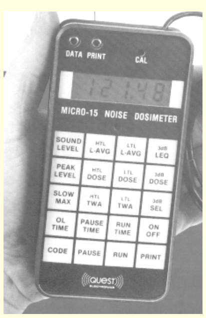
Noise Dosimeter Development Generation 3

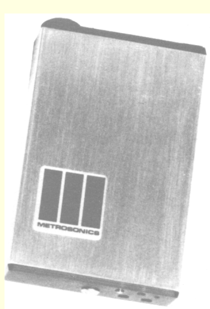
- 1981 – 1992 redesign after laboratory and field evaluation
- Improved technology to handle impulse/impact sound
- Multiple thresholds, operating time, sound level meter usage, improved dynamic range, frequency response, and impulse/impact waveform response.
- ½-inch or smaller microphone, low battery drain, LCD display, more than one function, integral readout,
- Conform to ANSI S1.25-1978 Noise Dosimeter Standard.

Noise Dosimeter Development Generation 3

- Field calibration techniques of a short duration.
- Remote microphone mounted on shoulder.
- Bendix ADS-3000, DuPont (AMETEK) Mark-Series, GenRad 1954, Metrosonics DB-301, Quest Micro-15 and Q-series.

Generation 3





Noise Dosimeter Development Generation 4

- 1992 – current
- Multi-functions w/time history, various versions for various customers, multiple dosimeters in one housing (combination of weightings, threshold, exchange rate, criterion levels, etc.)
- Time-history function inclusion
- Computer interface
- Shoulder mounted microphone or entire instrument on shoulder

Noise Dosimeter Development Generation 4

- Remote interrogation
- Quest NoisePro series, Larson Davis Spark, Casella DB Badge,

Generation 4

Dosimetry and Technology

- Noise dosimeter companies have come and gone.
- Some features worked well in laboratory but failed in the field environment.
- New technology has always been incorporated into dosimeter design.
- New standards, rules, and regulations help spur the development of newer and better instrumentation.

Noise Dosimeter Performance

- How do dosimeters perform?
- No standards in early days
- How to test?
  - Acoustical vs electrical
  - Microphone and electronics separate
  - Black Box approach
- How to evaluate?
- How to evaluate features?

Noise Dosimeter Performance

- 1972 – Confer, et. al. – 4 manufacturers, important to evaluate threshold, and exposure to sound – 3 of 4 returned to mfg. for repair or recalibration.
- *"From our field experience with the noise dosimeters evaluated, we found only one type repeatedly indicated results that we would have expected from sound level meter readings. Improvements are needed in three of the four instruments to make them reliable field units."*

Noise Dosimeter Performance

- 1973 – Leisure (NBS) conducted an evaluation on commercially available units for the USEPA on 6 personal and 2 stationary units from 8 manufacturers.
- Random incidence response, crest factor capability, exchange rate, performance over temperature, & dependence on battery voltage.
- Two manufacturers' units performed poorly.
- Need for a national standard and "*that users should be cautioned to carry out enough evaluation tests to ascertain that the devices are performing adequate for his purpose*."

Noise Dosimeter Performance

- 1974 – Stewart, et. al., (USBM) – 8 brands (3 of each model) of commercially available dosimeters.
- Black Box approach in diffuse and free field
- A-weighting response, integration accuracy and other tests
- "There is a substantial variation in measured exposure as calculated by instruments among and within different manufacturers."
- "…that some instruments exhibit nonlinearities in exposure calculations as a function of the dBA level."

Noise Dosimeter Performance

- 1977 – Yen, et. al., (USBM) reported on a second evaluation based on Stewart's first study.
- Black Box Approach
- A-weighting frequency response, exchange rate, crest factor for tone burst and broad band noise spectra, battery life, threshold, and over-exposure indicator.
- Units with rechargeable battery are erratic, battery life meter preferable to light, standby mode desirable, higher maximum dose readout needed.
- Results used for MSHA Acceptability Criteria for Noise Dosimeters (1978)

Noise Dosimeter Performance

- 1978 – Fortner, et. al. (NIOSH) – 9 Noise dosimeter models
- Extensive acoustical, electrical and environmental tests
- A detailed summary is presented on whether or not the instruments met NIOSH's proposed criteria.
- "*No single unit passed all of the tests*."
- "*Recognized that all of the tests and criteria should not be equally weighted*."

Noise Dosimeter Performance

- 1980 – Bucholtz and Yonovits examined the usefulness of noise dosimeters with respect to extended shifts
- *"..dosimeters performed as expected when exposed to acoustical stimuli for time periods exceeding eight hours."*
- *The accuracy of the dosimeters in this study tended to fall within a range of ± 2 dB from the expected value irrespective of the threshold setting."*

Noise Dosimeter Performance

- 1991 – Evans, et. al. (NIST) performed an evaluation for OSHA which evaluated the response of personal noise dosimeter to continuous and impulse-like signals for 10 commercially available models.
- 9 of 10 passed preliminary tests. 7 completed the evaluation.
- "*Except in a few isolated cases, the commercial dosimeters were in general agreement with the performance specifications of the appropriate ANSI Standard and with OSHA regulations.*"

Noise Dosimeter Performance

- There have not been any thorough, recent laboratory evaluations of current dosimeters because:
  - The cost to conduct such evaluations are quite extensive, expensive and many Federal Govt. agencies that conducted early evaluations no longer have the resources.
  - ANSI Standards are now in place
  - Most instrument users believe that when an instrument manufacturer indicates conformance to an ANSI standard, then the manufacturer has the detailed test results to backup this assertion. *This may not always be the case.*

Dosimeter Standards

- ANSI S1.4-1971 American National Standard Specification for Sound Level Meters
- ANSI S1.25-1978 American National Standard Specification for Personal Noise Dosimeters
- ANSI S1.25 – 1991 American National Standard Specification for Personal Noise Dosimeters
- ANSI S1.25 is currently undergoing revision in conjunction with the ANSI Sound Level Meter Standard.

Testing and Certification of Personal Noise Dosimeters

- NIOSH
  - April 16,1975, published a proposed requirement for the certification of sound level meter sets which became final.
  - December 30, 1977, published a “Proposed Rules for Certification of Personal Noise Dosimeter Sets”
  - NIOSH developed test procedures and evaluation criteria for personal dosimeters (Fortner, et. al.)
  - Meetings between industry, NIOSH and NIST regarding testing and evaluation of sound level meters and personal noise dosimeters.
  - With a change in administrations and reallocation of resources, NIOSH did not complete the regulation on the noise dosimeter certification program and ultimately withdrew the certification program for sound level meters.

Testing and Certification of Personal Noise Dosimeters

- MSHA
  - MSHA Acceptability Criteria for Personal Noise Dosimeter (IR-1072)
  - The certification program was in effect from 1978 until 2000. It ended with the new MSHA noise standard for occupational noise exposure.
  - List of Acceptable Noise Dosimeters which could be used to monitor miners’ noise exposure.
- Requirements for maximum readout capability, crest factor, exchange rate linearity, A-weighting response, pink noise response, and availability of a field calibration technique
- 2 of 3 instruments tested must pass all criteria
- Voluntary participation

Testing and Certification of Personal Noise Dosimeters - Today

- There are no regulatory requirements for testing and evaluation in the United States.
- There is no US certifying body.
- Instruments used for regulatory measurements are required to conform to ANSI Standards, but there is no mandatory testing and evaluation program.
- There are “Pattern Evaluation” testing requirements in IEC rules conducted by manufacturer.
- A 5-dB exchange rate unit is not covered in IEC standards.
- Let the buyer beware!

Summary

- There is a long history of direct reading instruments for noise exposure assessment.
- Performance evaluations have been conducted, but none recently.
- ANSI standards are in place and are being updated in line with IEC noise dosimeter standards.
- There is no testing and certification program in the United States for noise dosimeters.


D.R.E.A.M.
WORKSHOP

Dream

Kris Chesky, Ph.D.
Texas Center for Music & Medicine

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- Primary Question
  - Do intensity levels produced during routine ensemble-based instructional activities exceed allowable limits set by the National Institutes of Occupational Safety and Health?

- Methodology
  - Routine (daily) dosimeter measurements
    - Single point
  - Five rehearsal rooms
  - Inclusion criteria:
    - Leq ≥ 85dB(A) for rehearsal period
    - Minimum of 5 samples per ensemble

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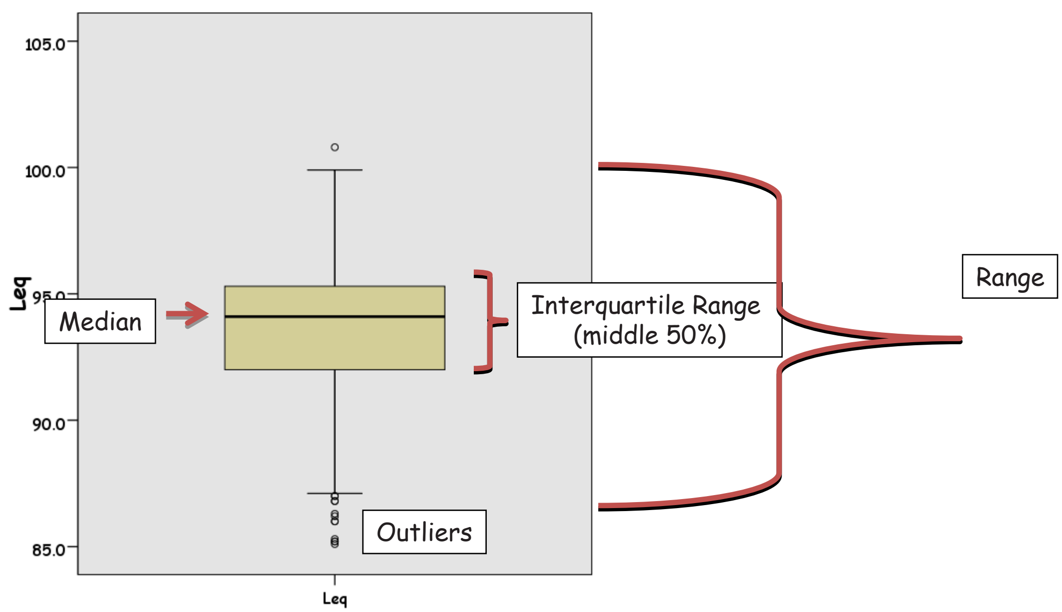
Sample Dosimeter Output

General Information		
Serial Number	21230	
Model	703+	
User		
Job Description	27	
Location	6	
Start Time	Monday, 03 March 2008 16:00:00	
Stop Time	Monday, 03 March 2008 16:50:00	
Run Time	00:50:00	
Pre Calibration	Thursday, 10 May 2007 09:56:00	
Post Calibration	None	
Calibration Deviation	---	
Sample Interval	1 Sec.s	
Note		
Results		
	Dose 1	
Dose:	134.7	%
Projected Dose:	1292.8	%
Leq:	96.1	dBA
TWA:	96.1	dBA
TWA (8)	86.3	dBA
Lmax:	104.3	dBA
Lpeak (max):	134.9	dB
Lmin:	51.5	dBA
Lep (8)	86.3	dBA
SE:	1.4	Pa²hr
Overload?	No	
Settings		
Exchange Rate:	3	
Threshold:	0	dBA
Criterion Level:	85	dBA
Criterion Duration:	8	hours
RMS Weight:	A Weighting	
Peak Weight:	Unweighted	
Detector:	Slow	
Gain:	0	dB

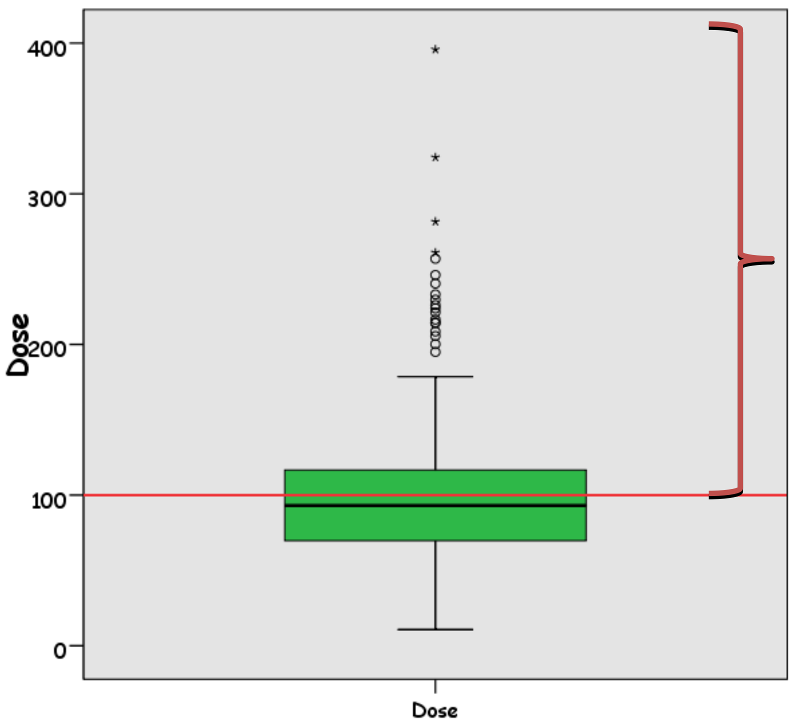
Dosimeter set according to NIOSH Publication No. 98-126
85dB Criterion Level and 3dB Exchange Rate
www.cdc.gov/niosh/docs/98-126

Leq Data (N=666 instructional activities)



Box and Whiskers Plot

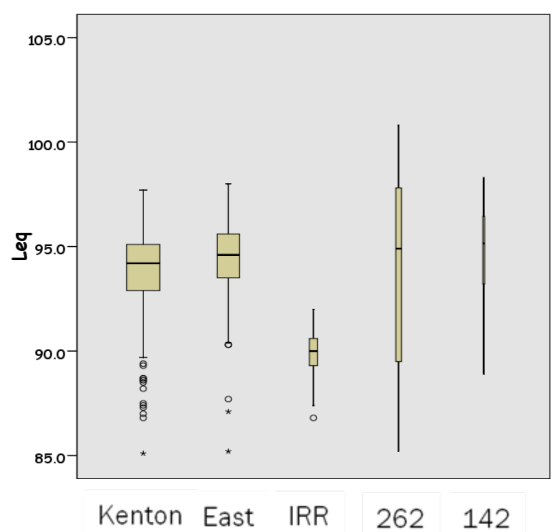
Dose Data (N = 666 instructional activities)

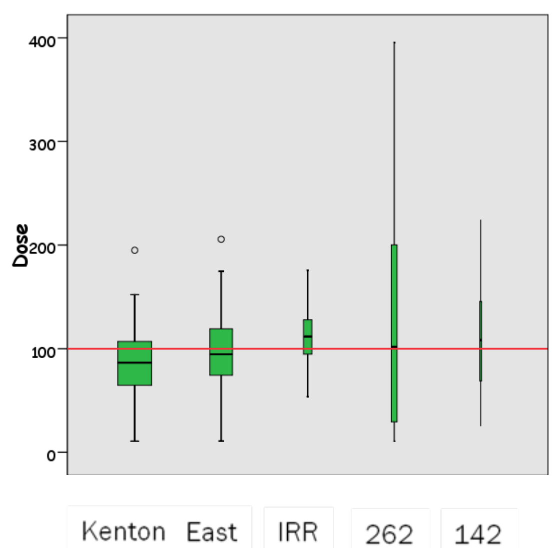


Results

Over forty percent of cases (N=282) exceeded maximum allowable exposure levels (100% Dose) for "entire" day.

Leq and Dose by Room






Kenton Hall (KH)
2418 ft²

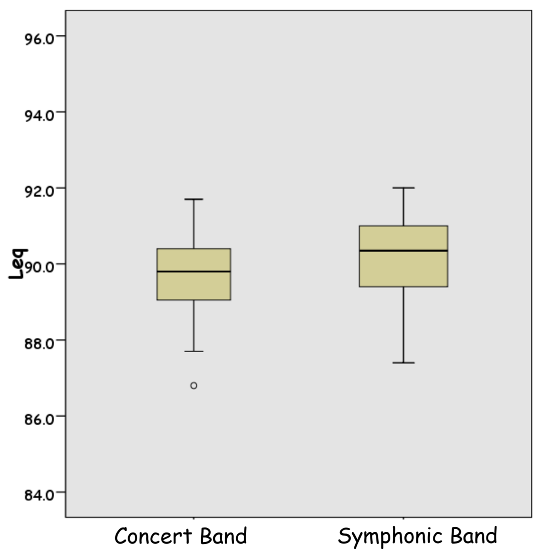

Lab East (East)
1007 ft²

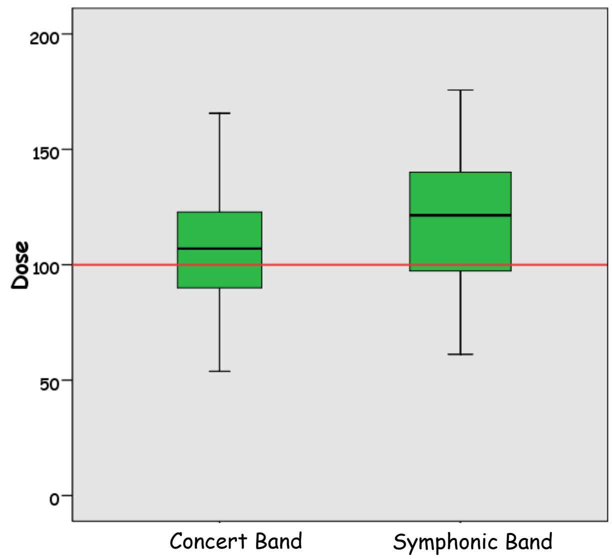

Instrumental Rehearsal Room (IRR) 3000 ft²


Room 262
1305 ft²


Room 142
1016 ft²

Ensembles in Instrumental Rehearsal Room

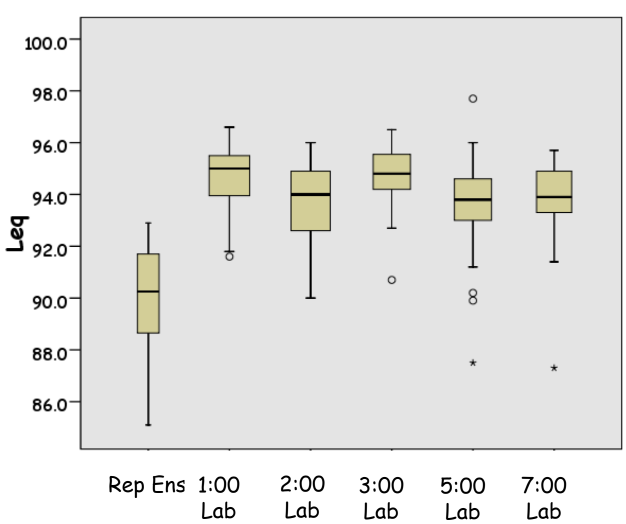


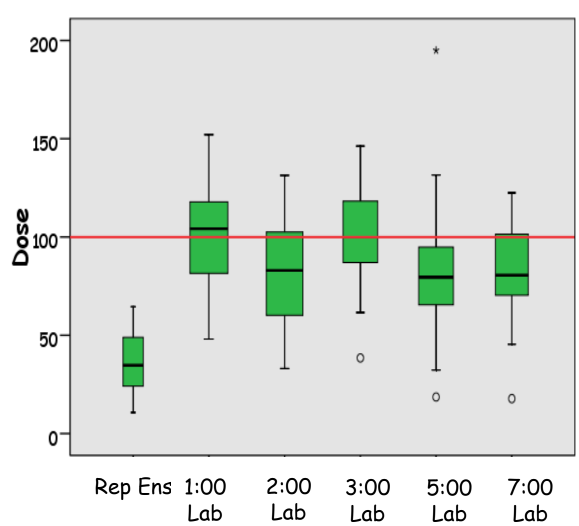


The two large wind bands represent a common ensemble type for most college programs. Both groups have traditional concert band balanced instrumentation with total membership of 70-80, depending on the pieces they are doing. The distribution is roughly as follows: Woodwinds - 50%, Brass - 45%, and Percussion - 5%.

Classes are scheduled for 3 hours.

Ensembles in Kenton Hall

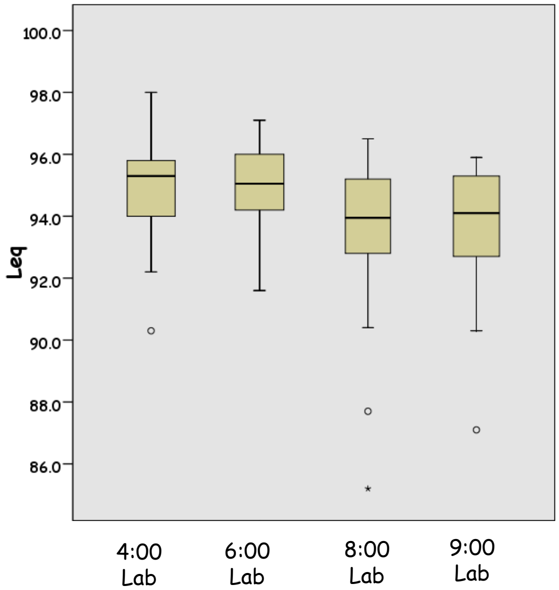


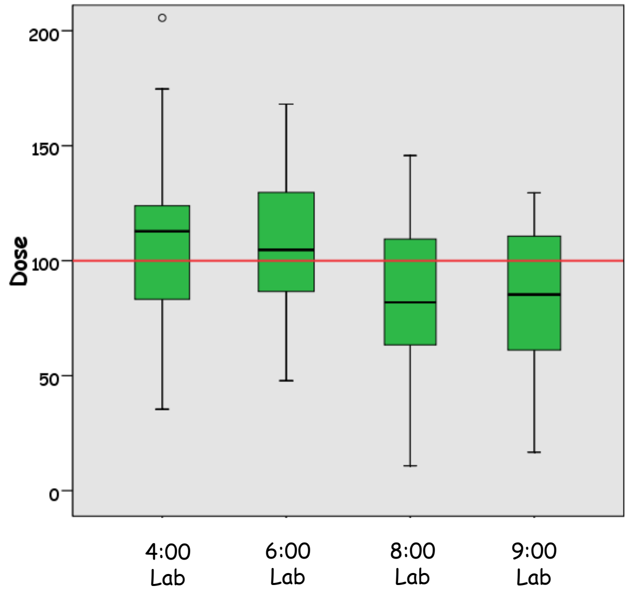


These large jazz (big) bands represent a common ensemble type for most college programs. Groups have traditional big band balanced instrumentation with total membership of 19. The distribution is as follows: Saxes (5), Trombones (5), Trumpets (5), Piano (1) Bass (1), Drum-set (1), Guitar (1).

Classes are scheduled for 50 minutes.

Ensembles in Lab East

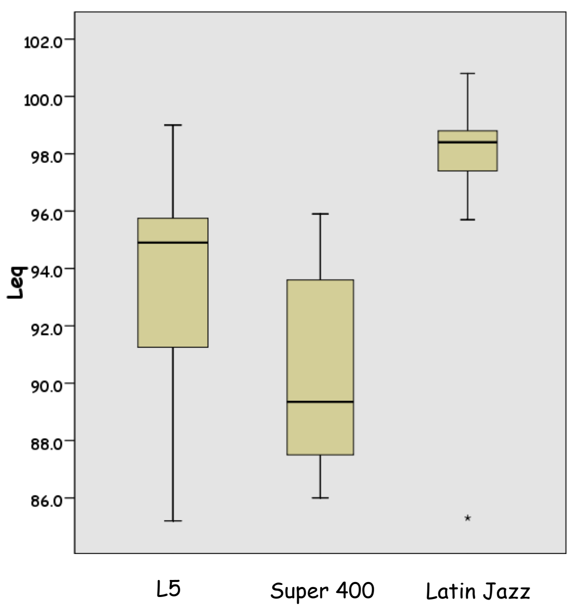


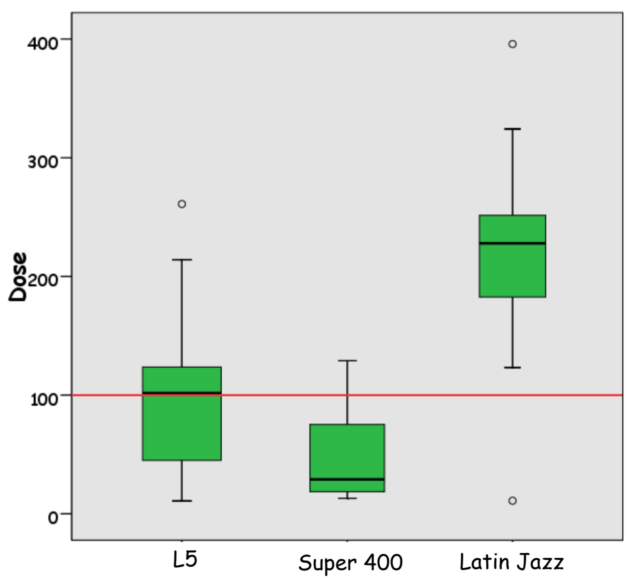


These large jazz (big) bands represent a common ensemble type for most college programs. Groups have traditional big band balanced instrumentation with total membership of 19. The distribution is as follows: Saxes (5), Trombones (5), Trumpets (5), Piano (1) Bass (1), Drum-set (1), Guitar (1).

Classes are scheduled for 50 minutes.

Ensembles in Room 262

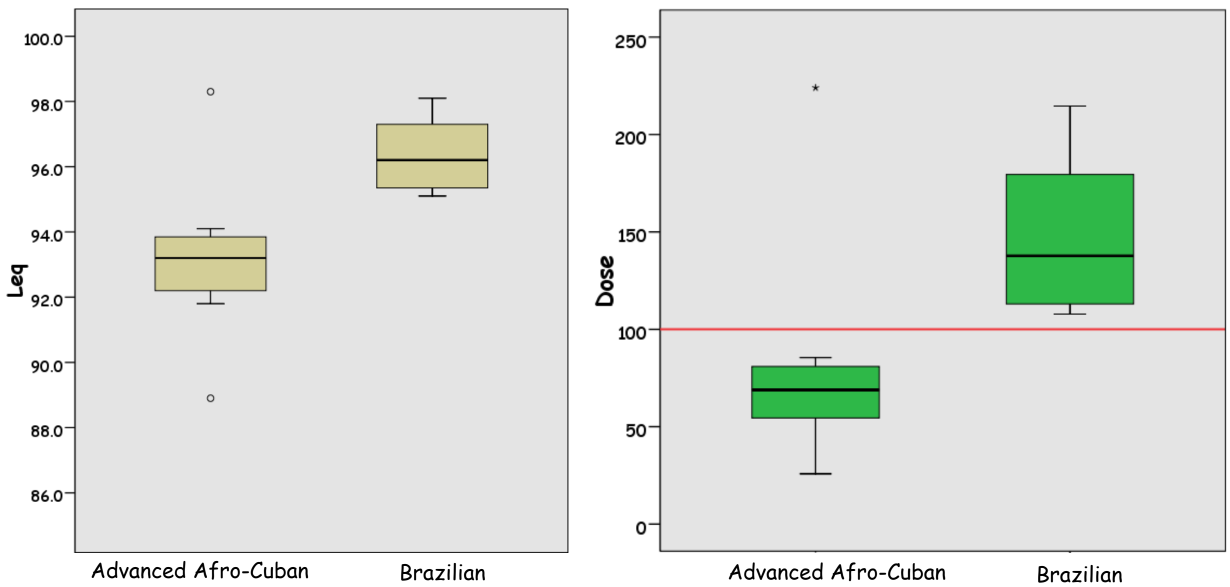




L5 and Supper 400 are guitar ensembles comprising 5 guitars, drum-set and electric bass. The Latin Jazz ensemble includes 15 members featuring Saxes (3), Trombones (2), Trumpets (3), (1) Piano (1) Bass (1), Vibraphone (1), Guitar (1), Conga (1), Timbales (1), Bongo (1).

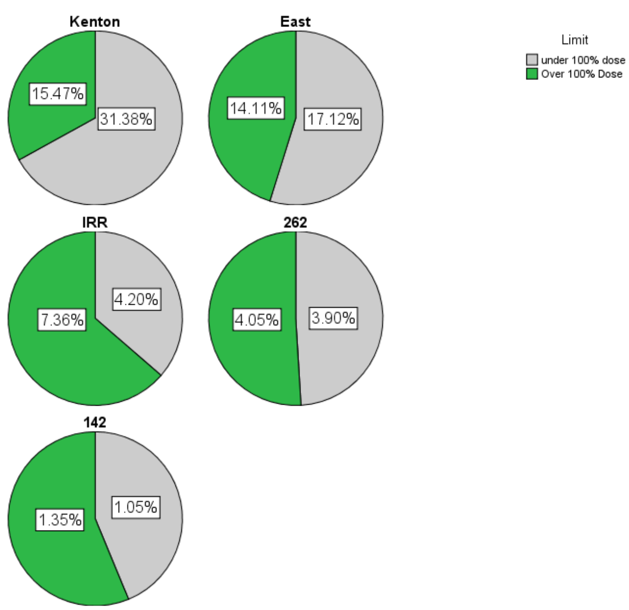
Classes are scheduled for 50 minutes.

Ensembles in Room 142



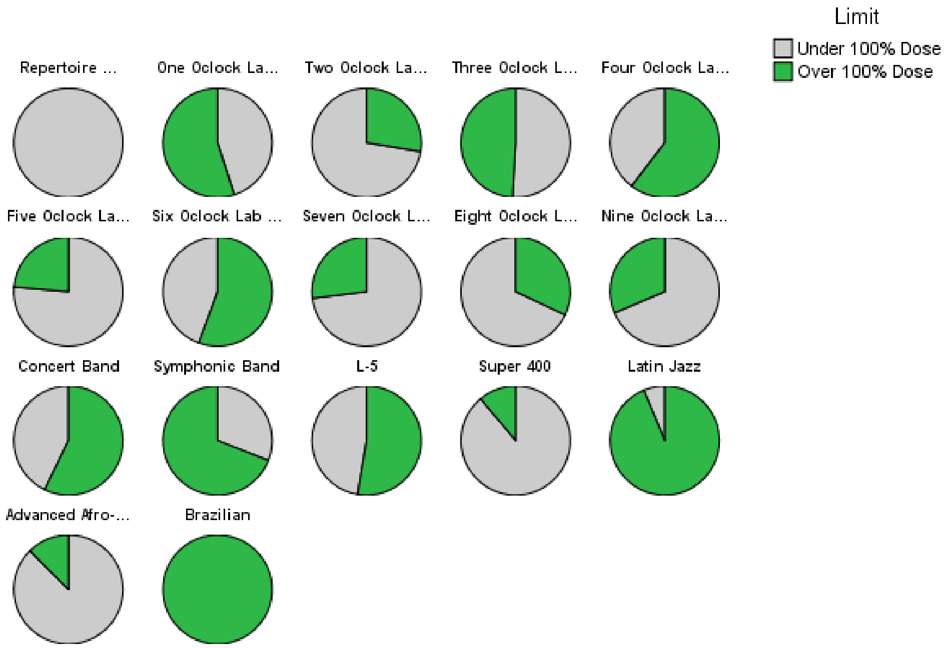
The Afro-Cuban and Brazilian ensembles are purely percussion ensembles. The Afro-Cuban group comprises 13 total musicians playing Congas (4), Cata (1), Clave (1), Shakers (3), Cajon (1), Batas (3). The Brazilian ensemble comprises 6 musicians playing: Surdo (2), Tamborims (2), Shaker (1), Snare Drum (1).

Percentage over 100% by Room



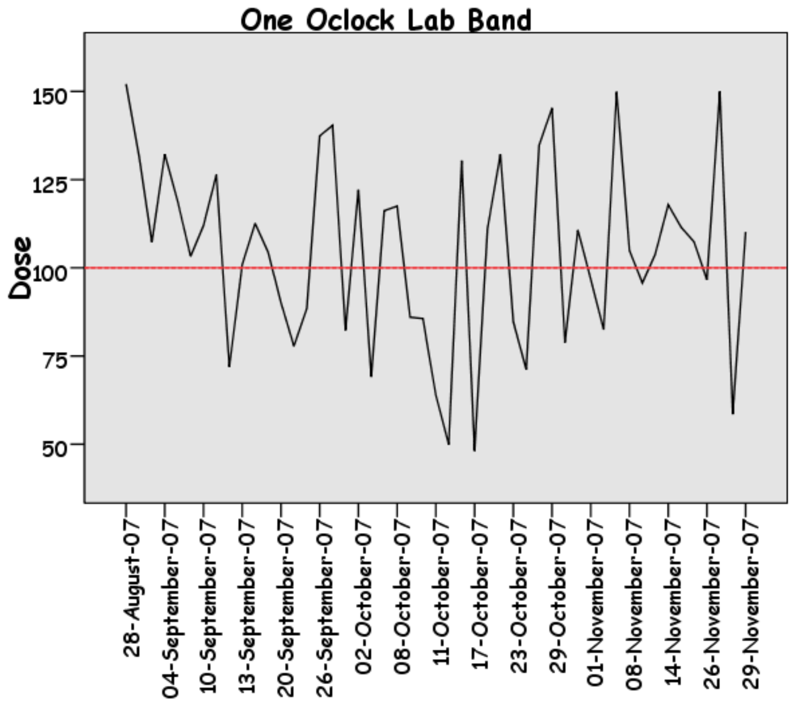
Numbers represent percent of total number of instructional activities (N=666)

Percentage over 100% by Ensemble



- **Primary Question**
  - Do intensity levels produced during routine ensemble-based instructional activities exceed allowable limits set by National Institutes of Occupational Safety and Health?
- **Answer**
  - YES! Dosimeter measurements show that routine ensemble-based instructional activities do exceed allowable limits. These limits are for the entire day. For most music majors, participation in an ensemble represents a fraction of total exposure per day. Exposures are cumulative.

– Data show large degrees of both inter and intra ensemble variability of intensity levels and suggests a multi-factorial set of influences.



Problems with dosimeter-based assessment.

- Dosimeter-based sound intensity characterizations and risk indices fall short in providing the necessary detail for adequately understanding a musical event.
- Interpretation and intervention efforts focused on reducing risk are often misguided and ineffective.
- In fact, most are unfounded, costly, and in some cases introducing other problems.

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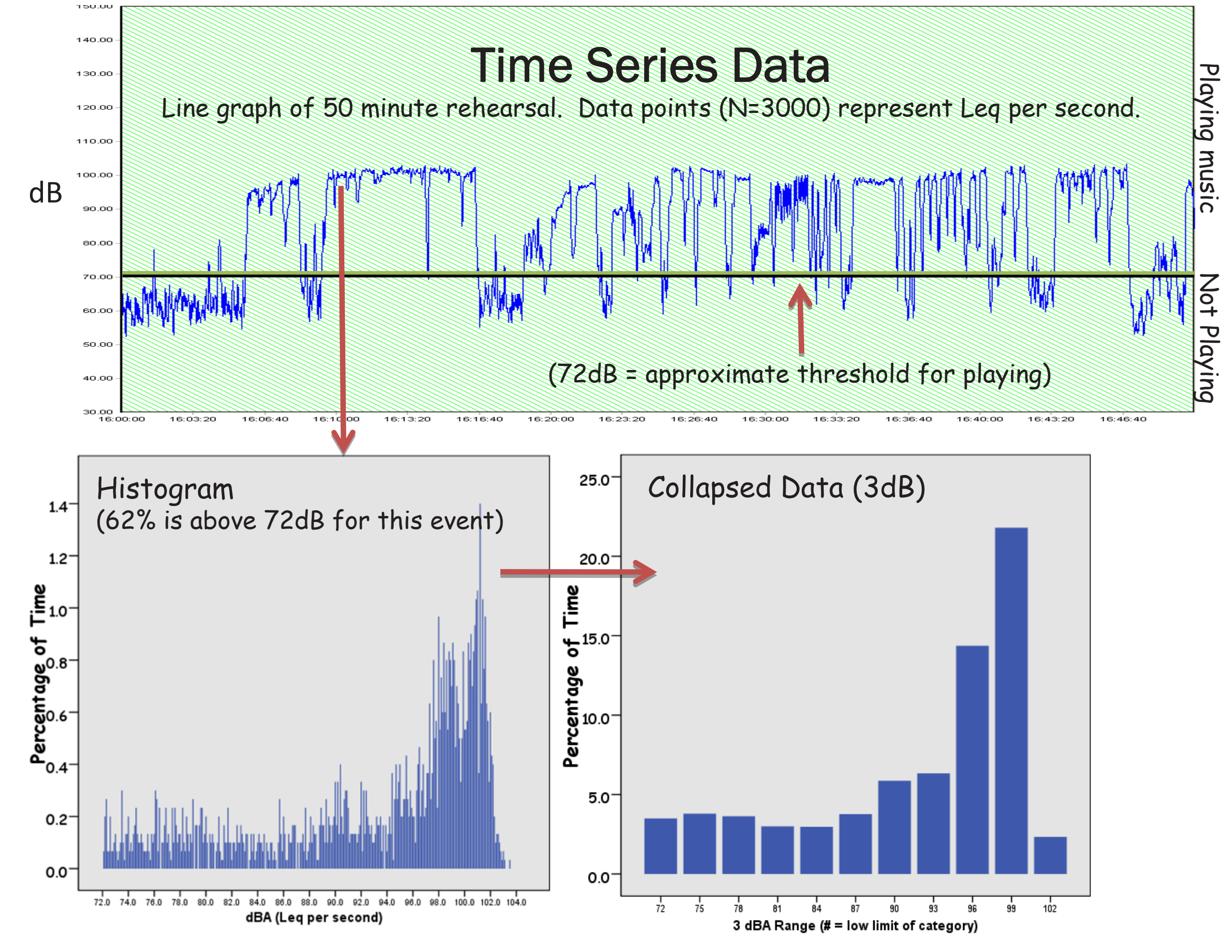
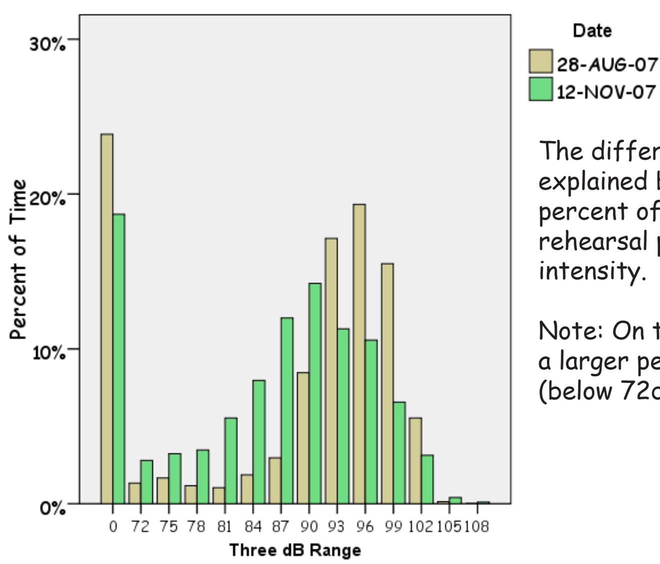


Example of highest Leq not resulting in highest dose

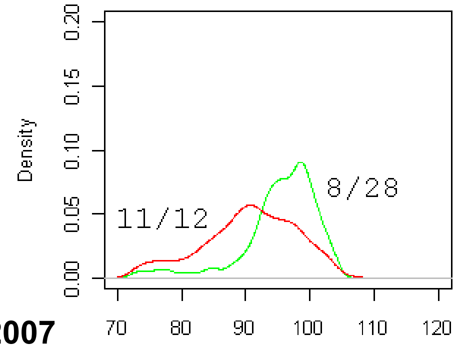
On November 12th, the 1 O'clock Lab Band reached 110.7 dB representing its maximum Leq/sec for the entire semester. The dose on this day was 95.7%.

Maximum Dose for entire semester was 152% on August 28th

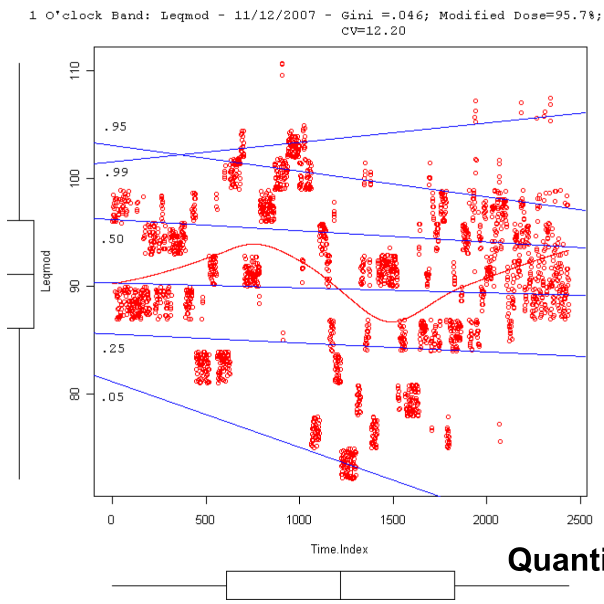


The differences between these two days can be explained by observing the differences in the percent of time spent during the 50 minute rehearsal periods across various levels of intensity.

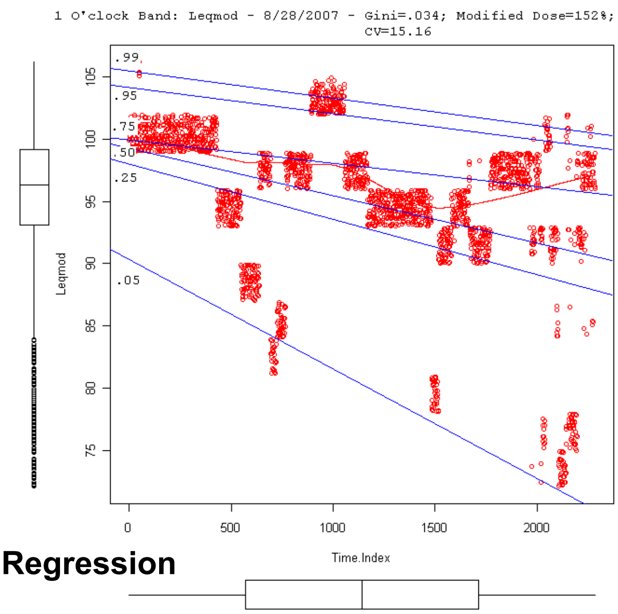
Note: On the day with the higher dose (Aug. 28), a larger percent of time was spent not playing (below 72dB).



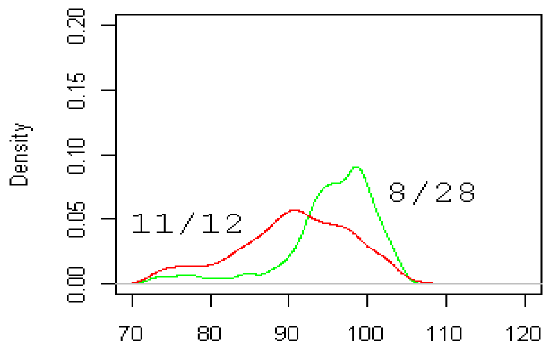
1 O'clock Band: 11/12/2007



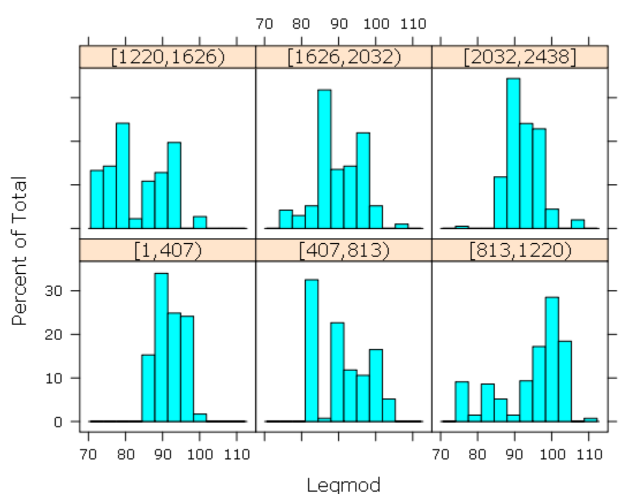
1 O'clock Band: 8/28/2007



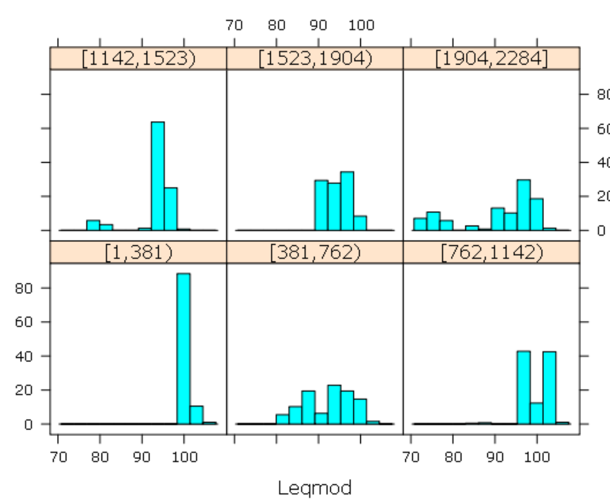
Quantile Regression



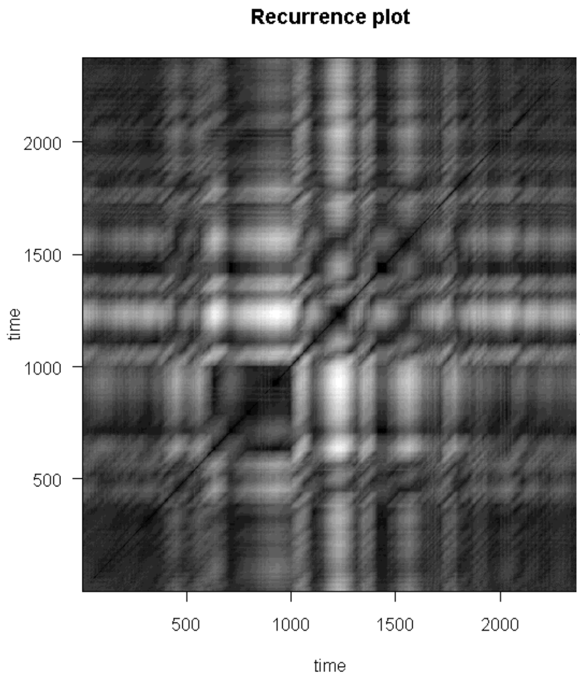
1 O'clock Band: 11/12/2007
Distribution of Leqmod by Time.Index



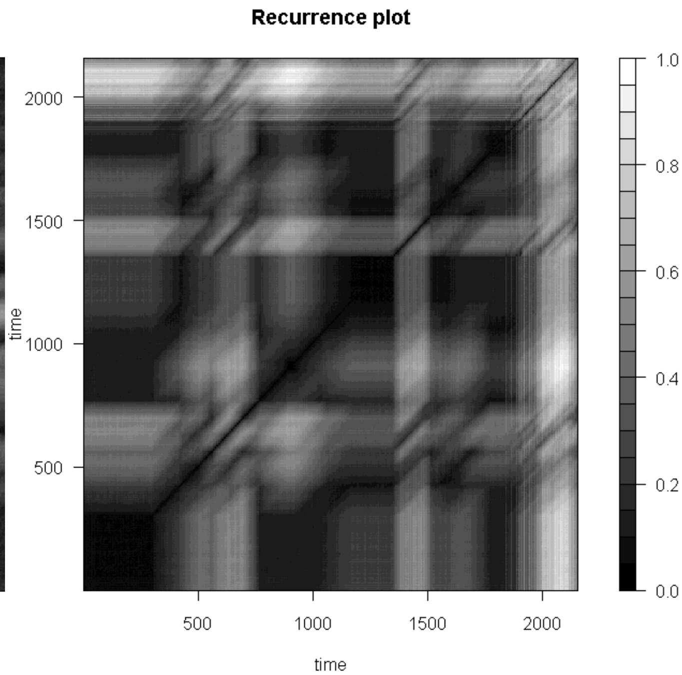
1 O'clock Band: 8/28/2007
Distribution of Leqmod by Time.Index



1 O'clock Band: Leqmod - 11/12/2007
Gini =.046; Modified Dose=95.7%; CV=12.20

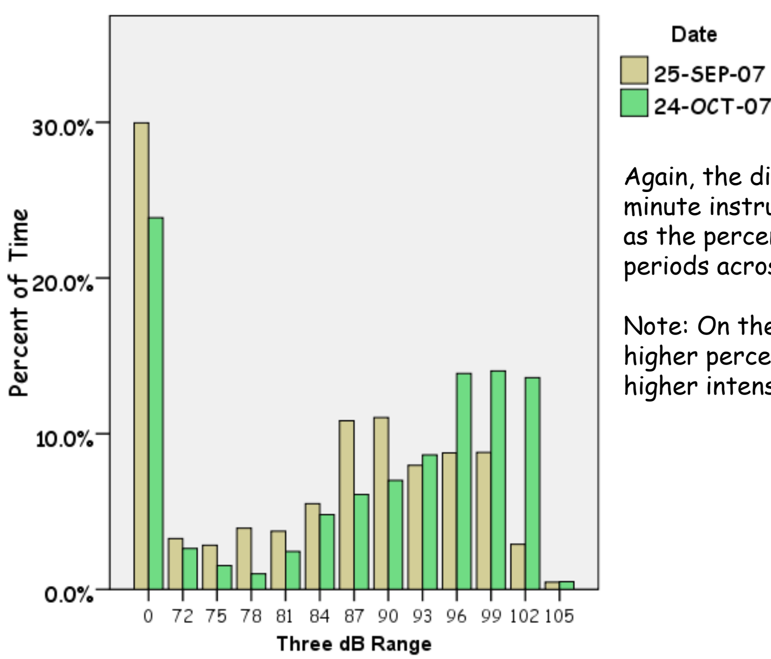


1 O'clock Band: Leqmod - 8/28/2007
Gini =.034; Modified Dose=152.1%; CV=15.16



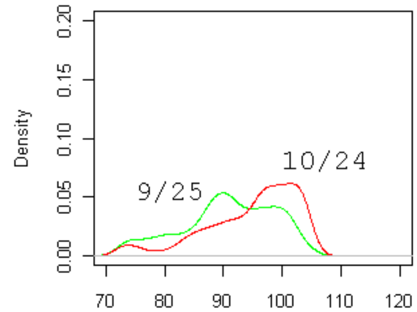
Equal max Leq/sec with different doses

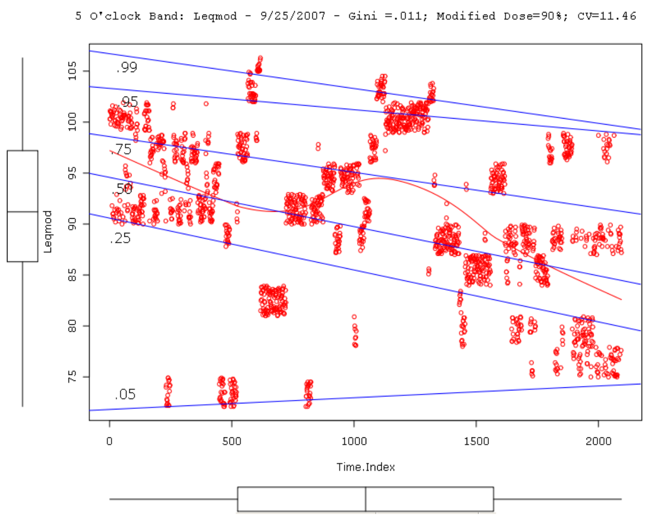
Representing the maximum Leq/sec for the entire semester, the 5 O'clock Lab Band reached 106.3dB on both September 25th and on October 24. However, the doses associated with the two educational activities were 90.7% and 195% respectively.

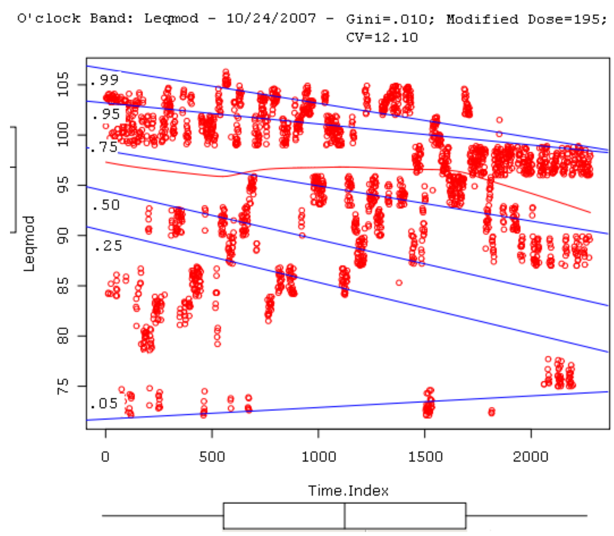


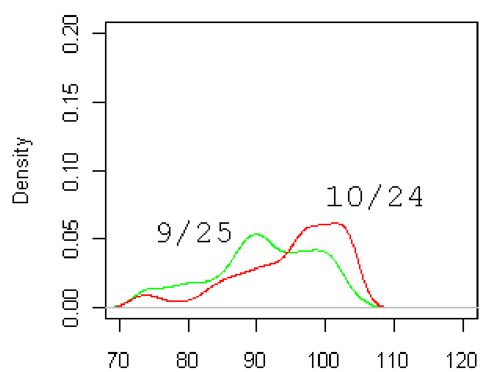
Again, the differences between these two 50 minute instructional activities can be observed as the percent of time spent during rehearsal periods across various levels of intensity.

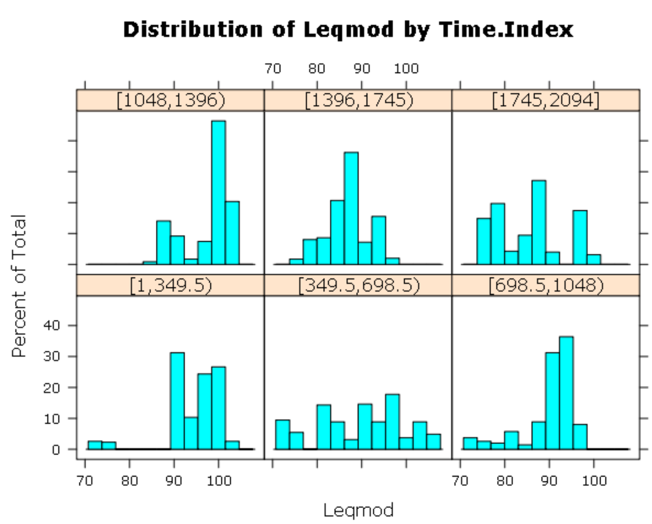
Note: On the day with the higher dose (Oct 24), higher percentages of time were spent at higher intensity levels.

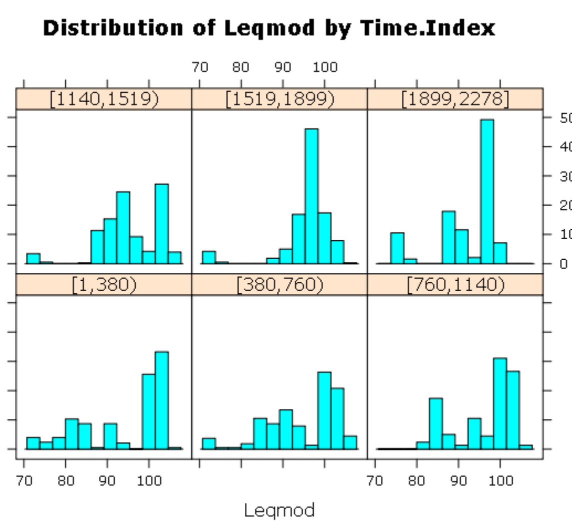

Density
10/24
9/25

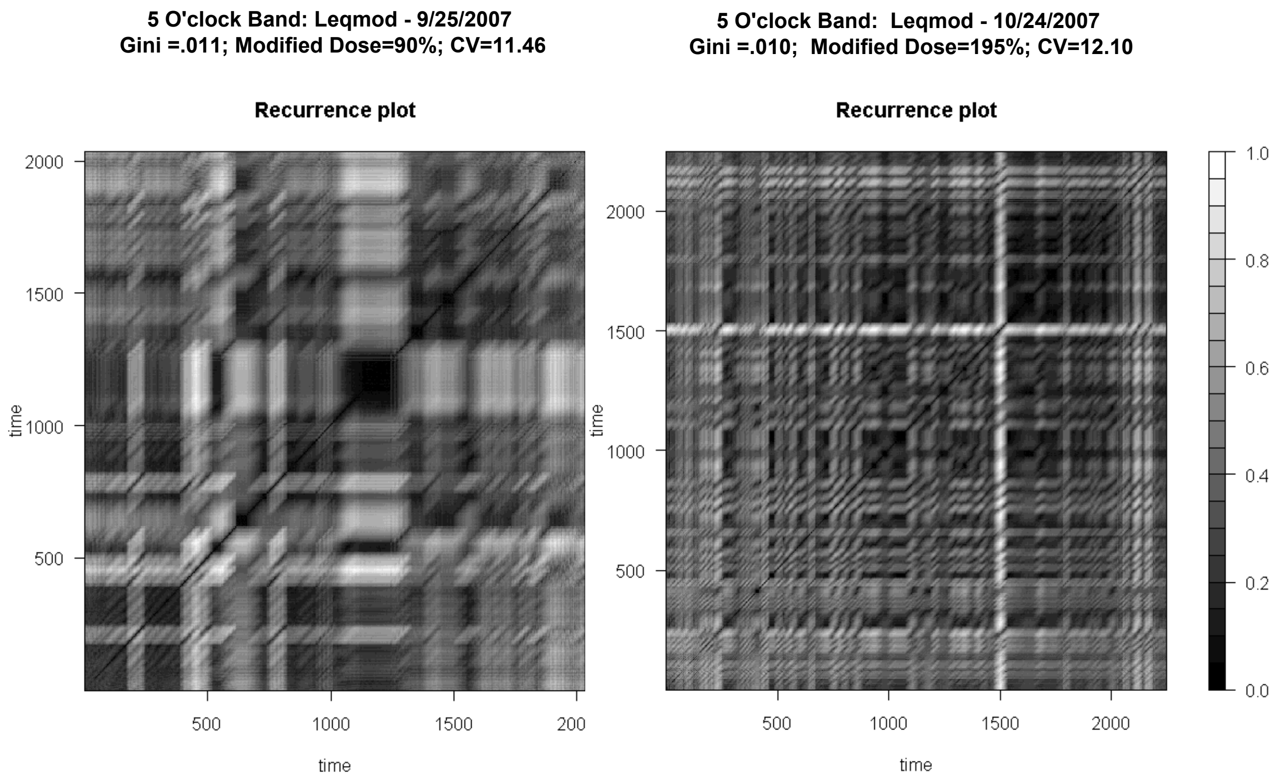

5 O'clock Band: Leqmod - 9/25/2007 - Gini =.011; Modified Dose=90%; CV=11.46
Leqmod
Time.Index


O'clock Band: Leqmod - 10/24/2007 - Gini=.010; Modified Dose=195; CV=12.10
Leqmod
Time.Index


Density
10/24
9/25

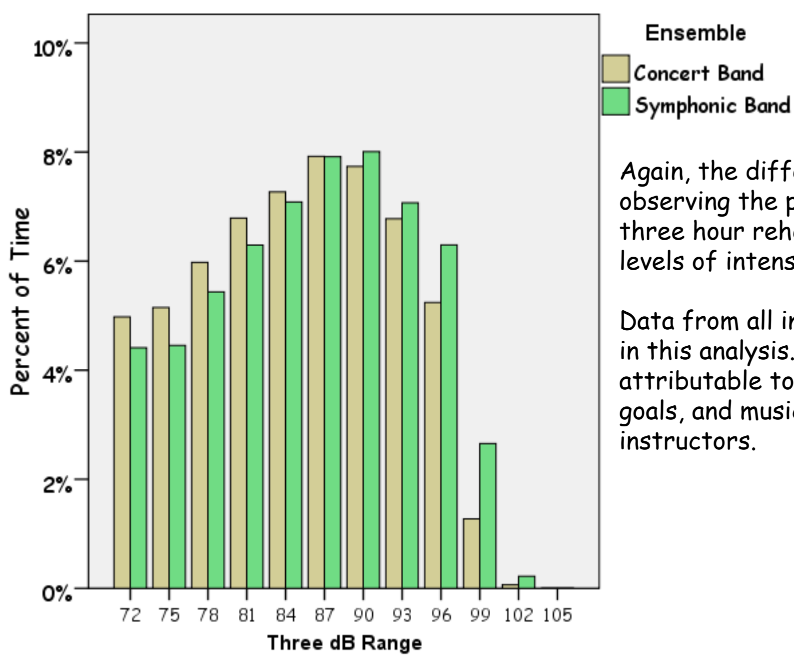

Distribution of Leqmod by Time.Index
[1048,1396)
[1396,1745)
[1745,2094]
[1,349.5)
[349.5,698.5)
[698.5,1048)
Percent of Total
Leqmod


Distribution of Leqmod by Time.Index
[1140,1519)
[1519,1899)
[1899,2278]
[1,380)
[380,760)
[760,1140)
Leqmod



Tendencies

Both the Concert band and Symphonic band spend nearly identical amounts of time (40%) below 72dB. The average dose for these three hour instructional activities for the Concert band (93.6%) is lower compared to Symphonic band (121.0%).



Again, the differences can be explained by observing the percent of time spent during three hour rehearsal periods across various levels of intensity.

Data from all instructional events are included in this analysis. Differences may be attributable to selected literature, educational goals, and musical expectations of the ensemble instructors.

More questions

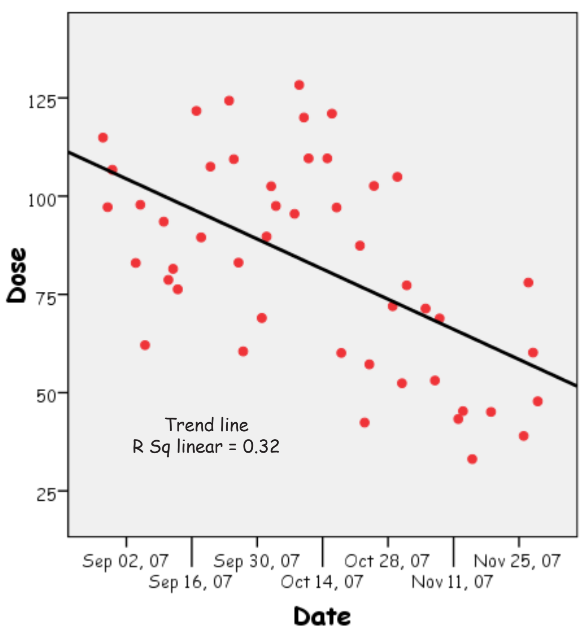
What are the relationships between “distribution of time spent at various intensity levels” and the “development of performance skills”?

What are the relationships between musical dynamics and risk levels?

Can schools of music prepare future ensemble directors to instruct effectively with lower risk?

Performance Practices and Risk Levels

Representing dose levels over one semester, the scatter-plot and fit line for the 2 O’clock Lab Band shows an important trend of decreasing dose over time. It is my personal belief that this data reflects one educational goal to play music with increased dynamics by practicing, and therefore spending more time, playing at soft and medium intensity levels.



Professor Riggs and the 2 O’Clock Lab Band


D.R.E.A.M.
WORKSHOP

PHYSIOLOGICAL BASIS FOR TIME-DOMAIN DIRECT-READING NOISE HAZARD ASSESSMENT

G. Richard Price
Auditory Hazard Analysis, Charlestown, Maryland
AHAnalysis@comcast.net
410 287-8503

NIOSH 2008 DREAM Workshop
November 13, Hilton Crystal City
Washington, DC

Why "a physiological basis"?

- Meters are designed to measure acoustic parameters
- The relevant parameters are those that predict hazard best for the ear
- The ear is a physiological system
- Understanding the physiological basis for hearing hazard should promote non-arbitrary (and better) measures

Approach in today's talk

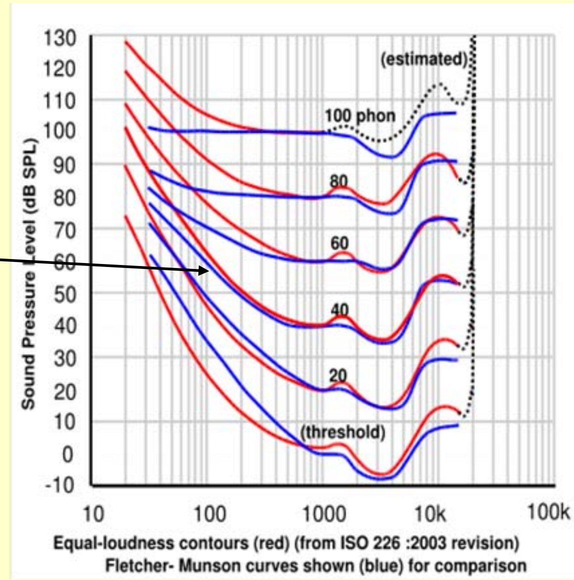
1. Use theoretically-based analyses connected to ear's physiology (desirable for generality)
2. Consider what could be done immediately for a meter
   – Two technical approaches needed
     - At lower pressures (metabolic mechanisms)
     - At higher pressures (mechanical disruption mechanism)
3. Propose what might be done in the near future and illustrate the benefits

Today: use A-weighted energy at lower SPLs (below 130-140 dB)

- Easily measured
- Readily integrates hazard from different sources
- Already used in US, Europe and elsewhere
- Common standards a good thing for world trade and inter-operability requirements
- Has a modest theoretical basis

Basis for A-weighting

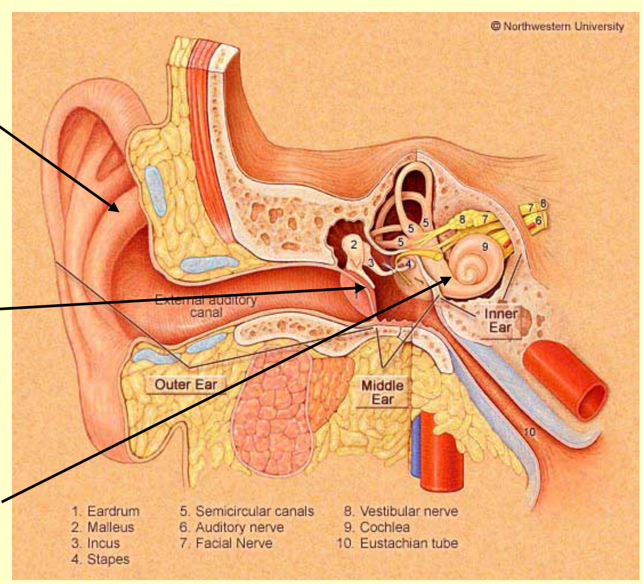
Fletcher-Munson equal loudness contour at 40 phon level



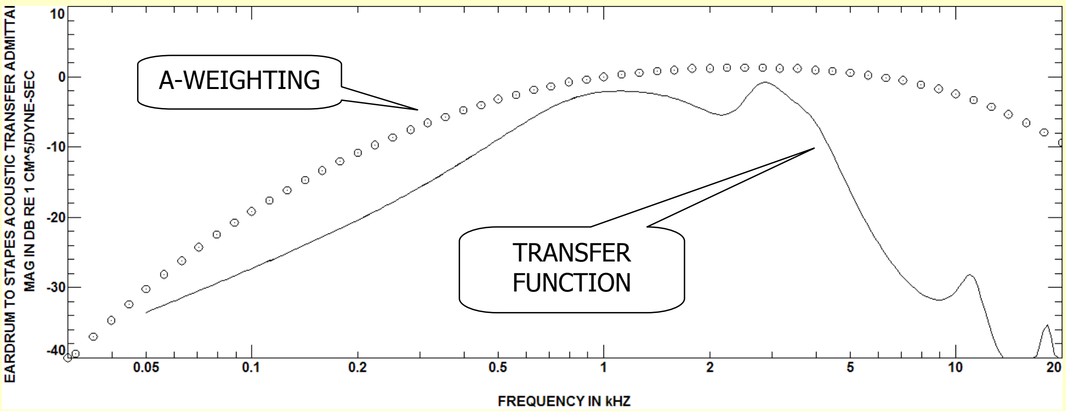
Physiological basis for A-weighting

- Head, pinna, ear canal resonances influence sound path
- Middle ear resonances, masses, stiffnesses, affect path
- Effect: band-pass filter

- Cochlea a resistive load



Transfer function from free field to stapes and A-weighting compared



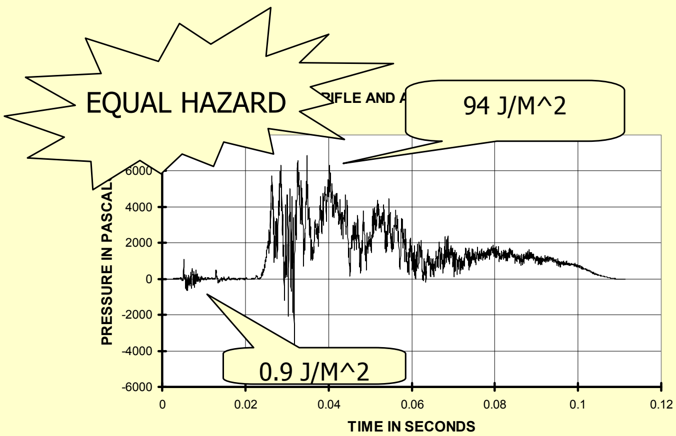
To a first approximation A-weighting represents constant energy at the cochlear entrance

Suggests the "equal energy hypothesis" as a hazard rating method

- For simplicity, just keep track of the energy during the <u>daily</u> exposure
  - Ignore temporal patterns, azimuth, physiological complexities
  - Follow total daily energy
- And that predicts hazard!
- Modest supporting data for 85-115 dB SPL
- Possible application up to 130-140 dB SPL

Trouble on the horizon at high SPLs

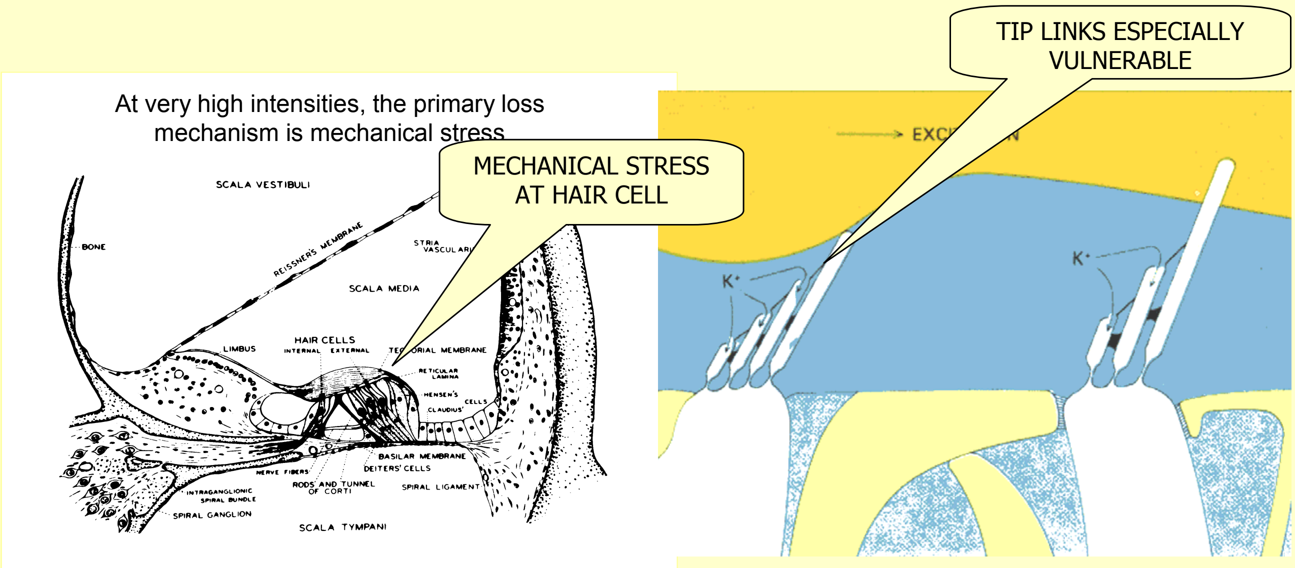
- At high levels (140 dB+) A-weighting doesn't work and neither do methods using peak pressure and duration, e.g.:



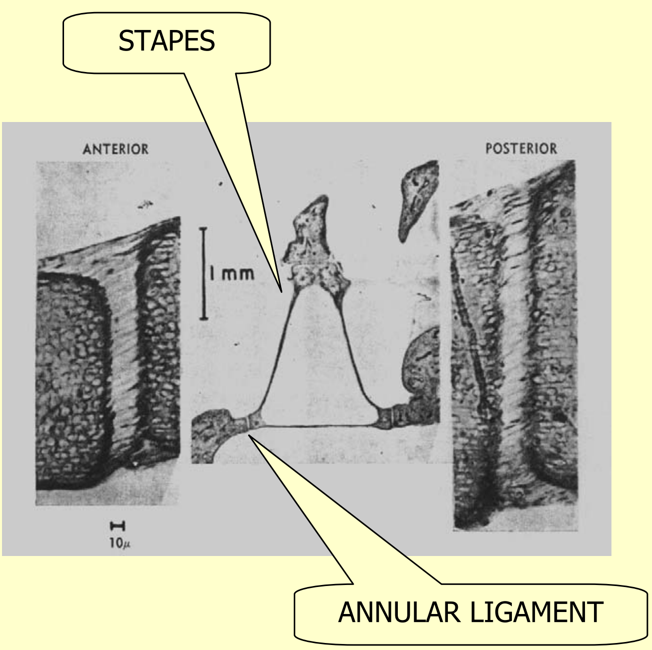
But

- Much basic research on the ear is available
  - Conductive path well described
  - Cochlear physiology understood
  - Mechanical stress thought to be loss mechanism at high intensities
- Theory allows computation of intracochlear events
- Computer power available

Physiological basis for loss at high intensities



The fly in the ointment – a non-linear middle ear at high intensities



- Middle ear remarkably linear with respect to amplitude (up to 130 dB) BUT
- Annular ligament peak limits stapes to about 10-20 microns displacement
- Effect profound – cochlear input peak-clipped at about 20 microns (could be 50 dB effect)

An audacious idea has become thinkable:

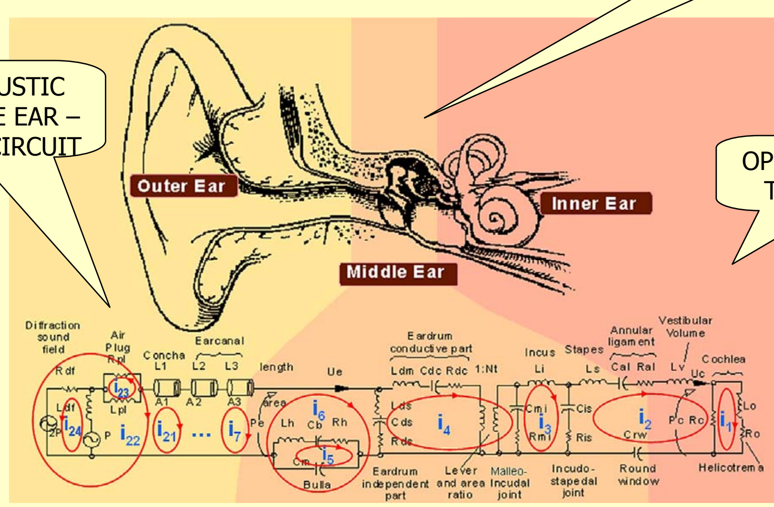
With all this new information and computational capacity, might it be possible to calculate stress at the hair cell level (*mechanism* of damage at *site* of damage) for intense impulses?

And so, the Auditory Hazard Assessment Algorithm for the Human (AHAAH) came to be

CONFORMAL WITH EAR'S STRUCTURE

ELECTRO-ACOUSTIC ANALOG OF THE EAR – A REALIZABLE CIRCUIT

OPERATES IN THE TIME-DOMAIN



Development of AHAAH

- Created and validated first for cat ear
- Circuit values changed to reflect human ear
- AHAAH validated for human ear (1996)
  – 70+ experiments with waveforms and human audiometry
  – AHAAH accurate 95% of cases
  – A-weighted energy accurate 30% of cases
  – MIL-STD 1474 accurate 38% of cases
- AHAAH <u>much</u> more accurate than existing methods
- New feature - time domain analysis of action (movie)

Basic algorithm within cochlea

- Basilar membrane displacement calculated (forcing function for hair cells)
  – Peak upward displacement of basilar membrane (in microns) squared
  – Summed at each of 23 locations (approx 1/3 oct spacing)
- Output in Auditory Risk Units (ARUs)
- 500 ARUs in one exposure = onset of PTS

Official status for the human version:

- Peer-reviewed
- Published (available for 10+ years)
- Accepted by SAE for analysis of airbag noise
- Accepted by Army for analysis of unprotected exposures, being evaluated for protected exposures
- No other method fits the data at high SPLs (150dB and up)

It can be done. But is it worth the trouble?

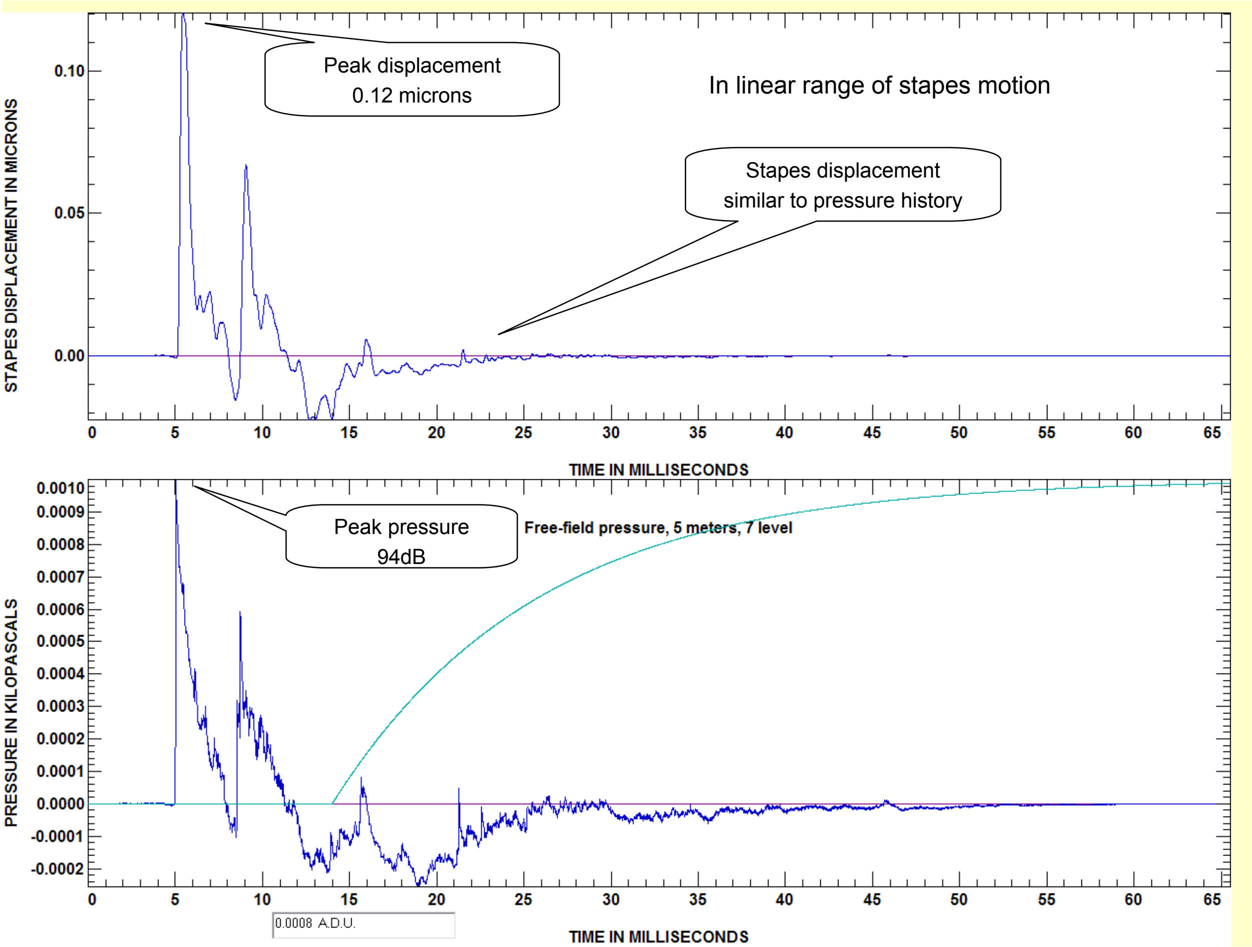
At high SPLs it is necessary!

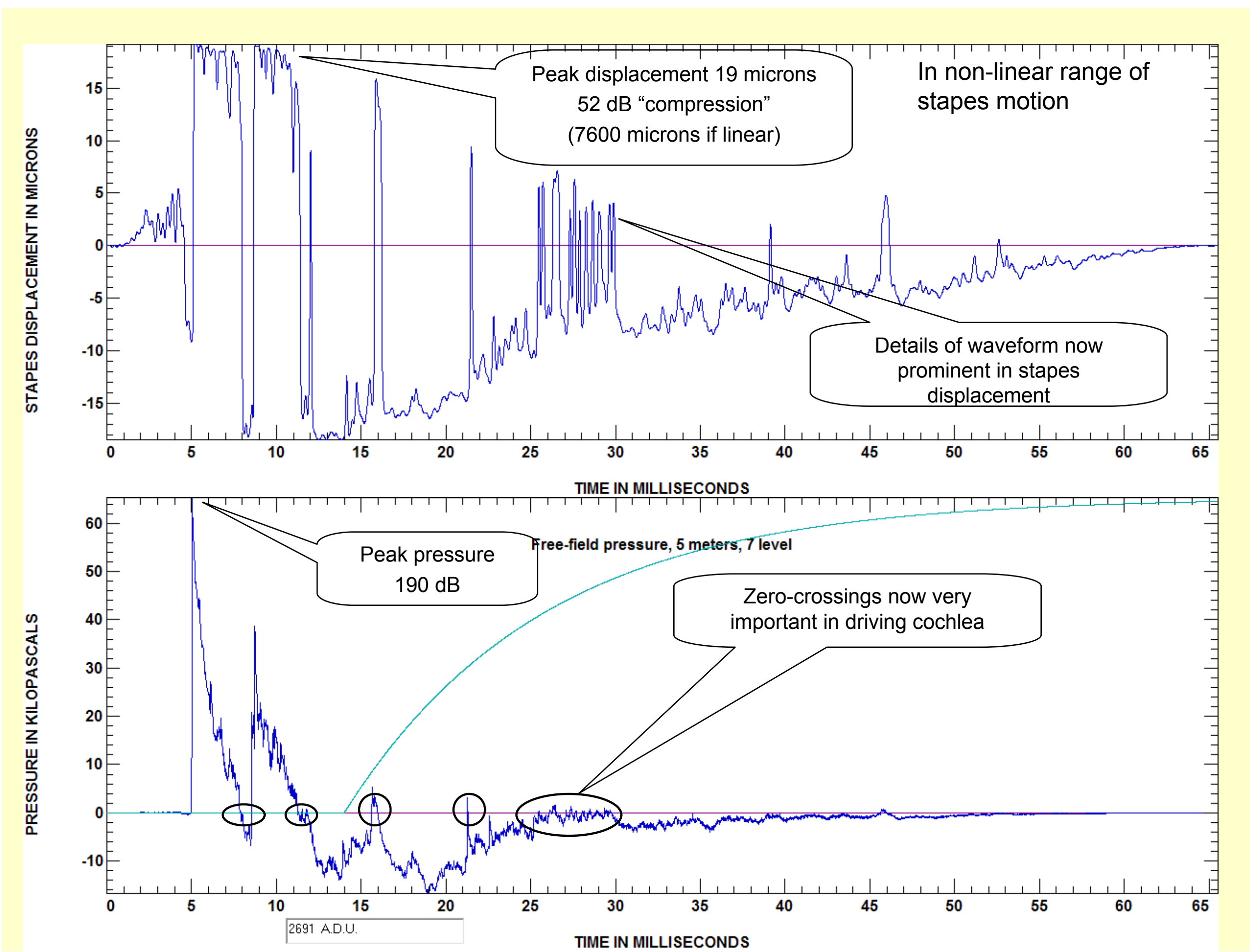
Special consideration at high SPLs

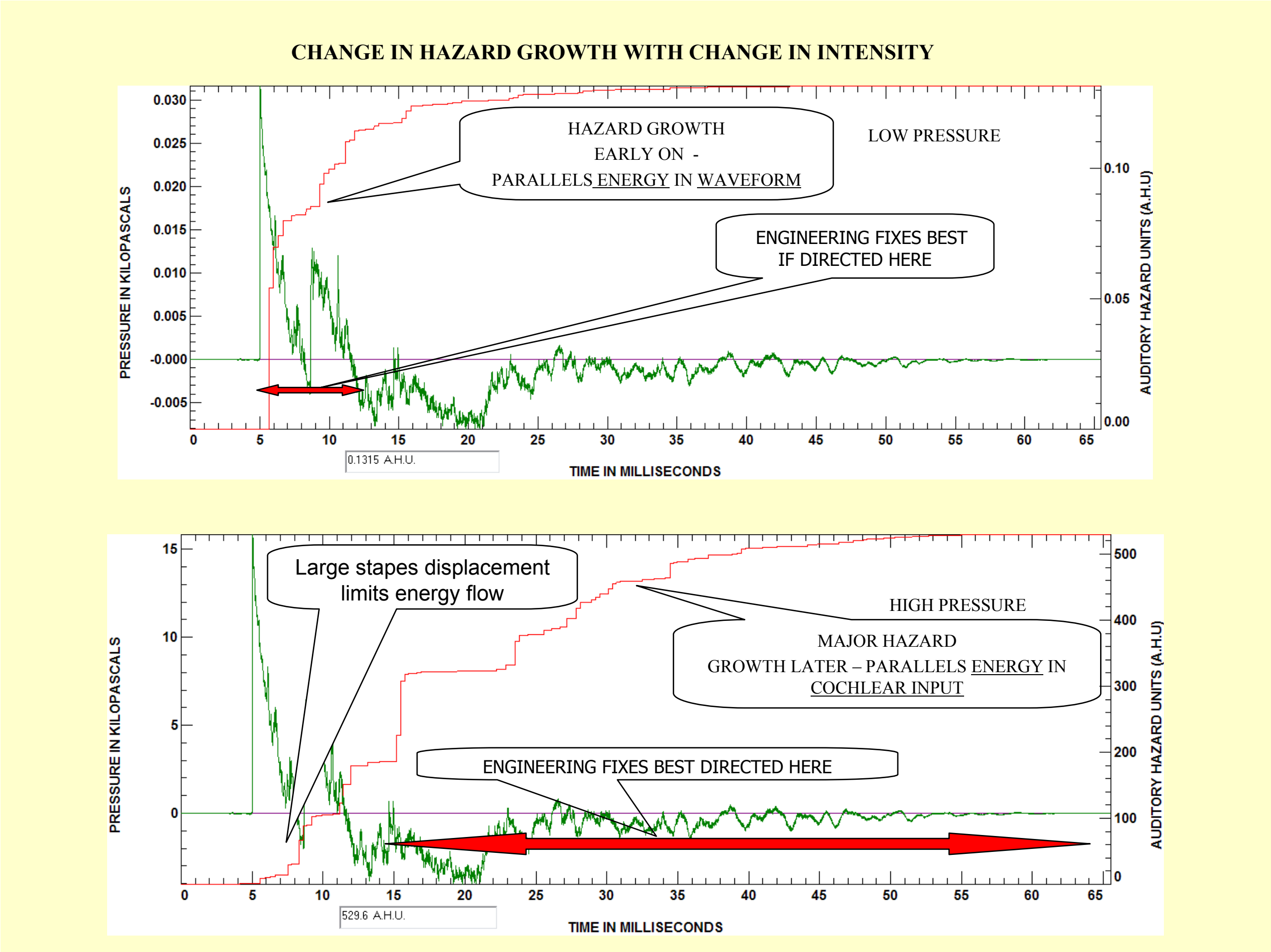
- Need for time-domain analysis greater as SPL rises
  - At lower levels exposures take years
  - Many uncontrolled elements
- At high levels, critical exposure may consist of <u>one</u> impulse – PTS instantaneous
- <u>Details critical</u>, especially if engineering solutions are to be implemented!

A peak-limiting stapes produces major effects at high intensities

- Consider the implications of stapes non-linearity
  - Peak-limits cochlear input
  - Modulates flow of energy as it limits – low frequencies (even infra-sounds) affect high frequencies
- Consider an example of limiting stapes displacement:
  - Calculated at 94 and at 190 dB PPL
  - Same waveform


Peak displacement
0.12 microns
In linear range of stapes motion
Stapes displacement
similar to pressure history
STAPES DISPLACEMENT IN MICRONS
TIME IN MILLISECONDS
Peak pressure
94dB
Free-field pressure, 5 meters, 7 level
PRESSURE IN KILOPASCALS
0.0008 A.D.U.
TIME IN MILLISECONDS


Peak displacement 19 microns
52 dB "compression"
(7600 microns if linear)
In non-linear range of
stapes motion
Details of waveform now
prominent in stapes
displacement
STAPES DISPLACEMENT IN MICRONS
TIME IN MILLISECONDS
Peak pressure
190 dB
Free-field pressure, 5 meters, 7 level
Zero-crossings now very
important in driving cochlea
PRESSURE IN KILOPASCALS
2691 A.D.U.
TIME IN MILLISECONDS



Recommendations for today's DREAM meter

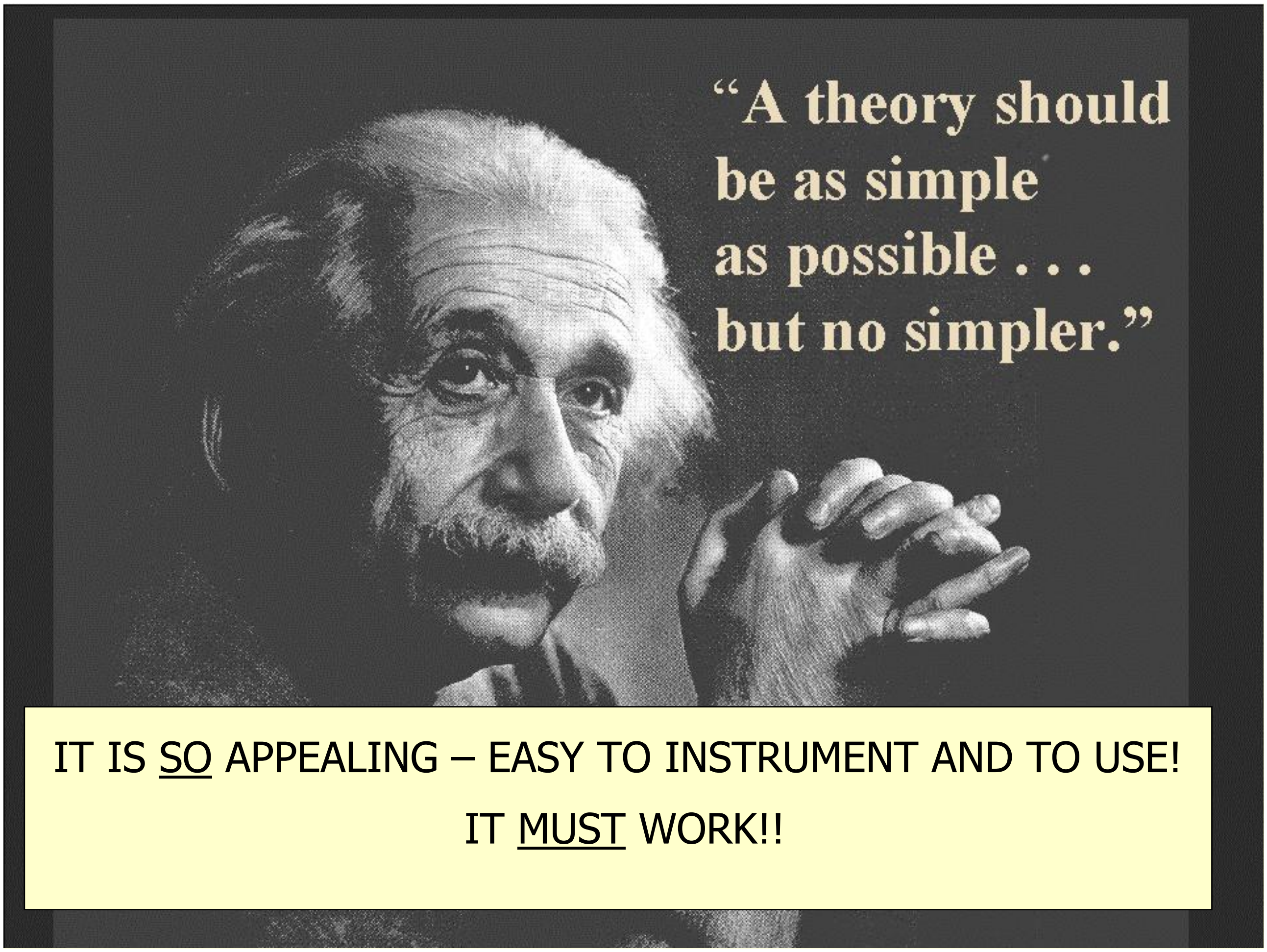
- Use A-weighted energy for 85-115 dB SPL
- Consider use up to 140 dBP
- Parallel analysis with AHAAH for SPLs above 140 dBP
- Recognize apples/oranges combination
  - Up to 115 dB: long-term slow accumulation of effect within ear
  - Above 140 dB: immediate PTS possible

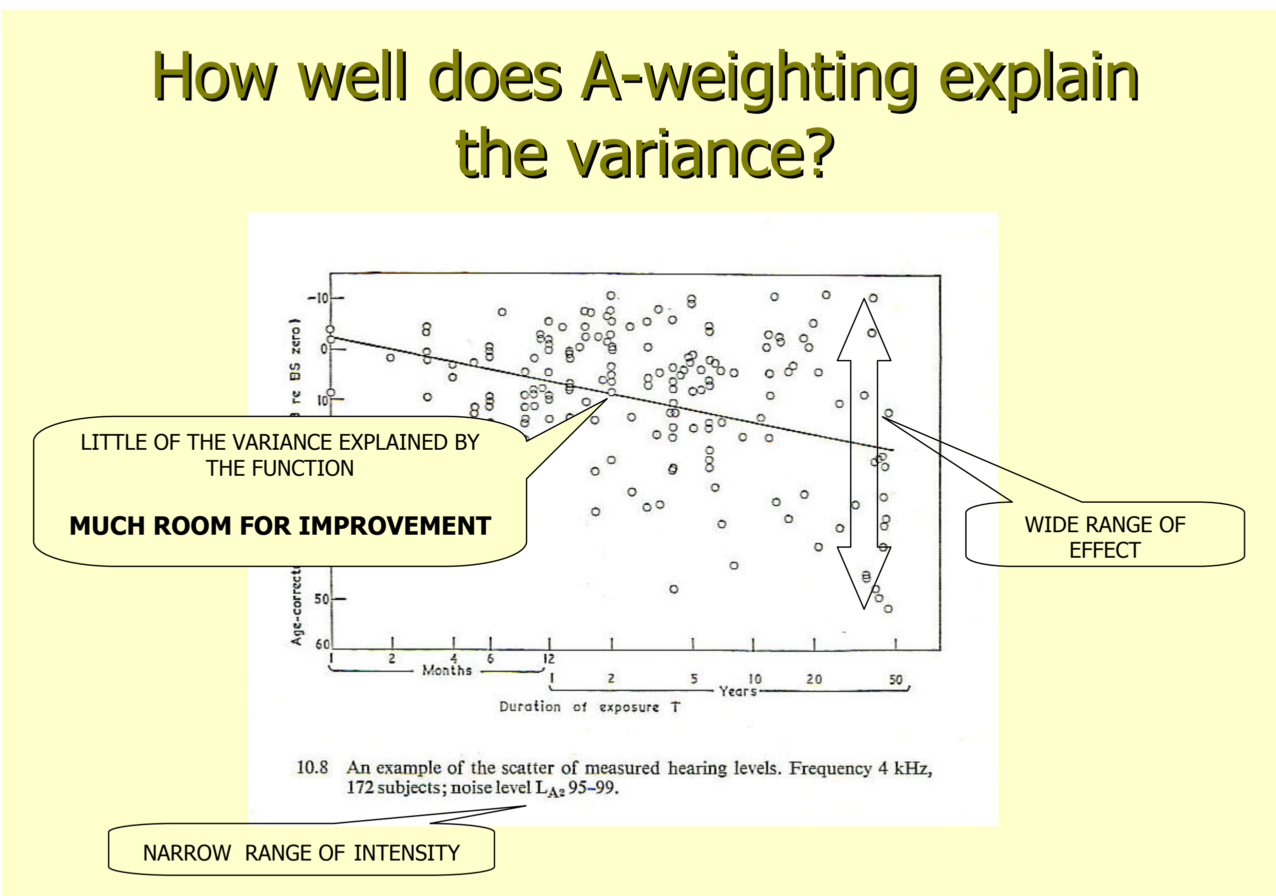
Part II

A Look at Tomorrow's Meter

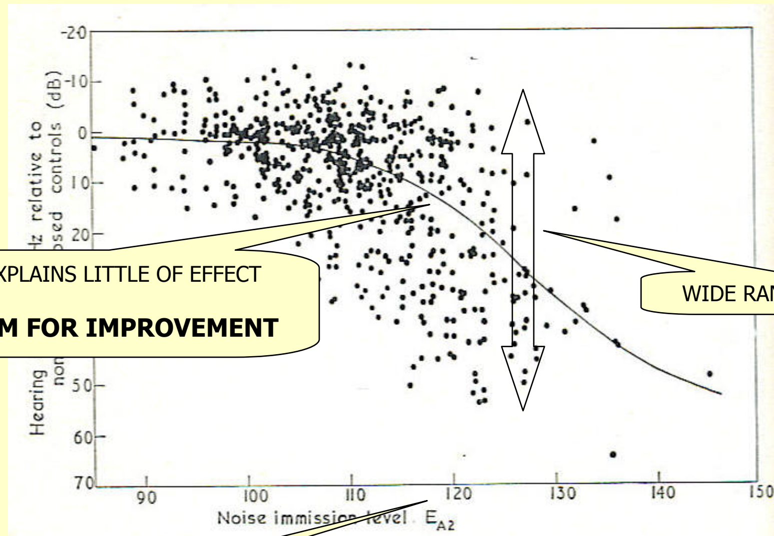
Another look at the "equal energy hypothesis" as a hazard rating method

- For simplicity, we just keep track of the energy during the daily exposure
  - Ignoring temporal patterns, azimuth, physiological complexities
  - Following total daily energy
- And that predicts hazard!


"A theory should be as simple as possible . . . but no simpler."
IT IS SO APPEALING – EASY TO INSTRUMENT AND TO USE!
IT MUST WORK!!


How well does A-weighting explain the variance?
LITTLE OF THE VARIANCE EXPLAINED BY THE FUNCTION
MUCH ROOM FOR IMPROVEMENT
WIDE RANGE OF EFFECT
NARROW RANGE OF INTENSITY
Months
Years
Duration of exposure T
10.8 An example of the scatter of measured hearing levels. Frequency 4 kHz, 172 subjects; noise level L_{A_2} 95–99.

How well does A-weighting explain the variance?



11.3 Indi... age-corrected hearing levels, at 4 kHz, relative to controls ...exposed to noise, plotted against noise immission level. Number of ...cts 581. Noise immission level $E_{A2} = L_{A2} + 10 \log (T/1 \text{ month})$.

Time for another audacious idea ?

With the predictive success of the model, why not improve predictive capacity and efficiency with a time-domain model of the ear designed for SPLs from 85 dB to 185 dB?

Clearly, a grand, unified, standard <u>desirable</u>

Desiderata

- Dose-meter in form
- Use full pressure history
- Manikin shape (a meter with pinnas):
  - Could correct for azimuth (20+ dB effect)
  - Allow evaluation of HPDs
  - Mini-meter in ear could work

Desiderata

- Critical physiological processes to be included:
  - Allowance for intermittency (recovery processes)
    - Ear benefits at lower intensities
      - Equal to a 6dB reduction in pressure!
      - SPLs in off-periods important (to allow recovery)(need to measure 60dB levels)
    - BUT ear <u>may not</u> benefit from intermittency at <u>high</u> intensities
      - Recovery slows, exposure "appears" longer
      - Loss <u>greater</u>
  - Adaptive middle ear muscle response
    - Up to 20 dB effect
    - Varies with time and stimulation conditions

Potential for improvement clear!

- Could explain more variance than A-weighting (presently <10% in modest range)
- Integrated method unifies analysis
- Non-arbitrary foundation (physiological processes) ensures usefulness of recommendations and promotes insight
- <u>Very</u> high accuracy probably not possible – too many uncontrolled human variables both during exposure and in off-periods

Suggested Priorities for NIOSH

- Move Toward Grand Unified Theory of Hearing Loss
  - Support research / analysis that seeks to quantify and integrate insights from acoustical and physiological research on auditory hazard.
- Promote development of wide-range capabilities
  - Microphones (60-190dB)
  - Analyzers (24 bit digitization at high rates)
- Promote development of comprehensive DRC for noise (provide legal basis for meter makers to use)

Suggested Priorities for NIOSH

- Support development of methods for rating HPDs
  - Acoustic manikin
    - Realistic physiology – skin, warm ear canals, etc.
  - Mathematical models of HPDs
  - Digital filter representations of HPDs

D.R.E.A.M.
WORKSHOP

Radiation

Direct-Reading Exposure Assessment Methods Workshop Agenda

Day 1 – continued Radiation

Session 5: Radiation
Monitors: Jeri Anderson and Mark D. Hoover (NIOSH), and Cynthia G. Jones (NRC)

Speaker/Title of Discussion

1. **Mark L. Maiello (Wyeth Research) Discussion of Critical Issues for Direct-Reading Exposure Assessment Methods in the Pharmaceutical Industry**

Rapporteur: Pam Drake (NIOSH)
Topics:

1. NIOSH role in radiation exposure assessment of workers in the context of other federal agencies: NRC, DHS, NIST, DOE, OSHA, EPA, DOD
2. Working definition of DRM for radiation
3. Status of current DRM for radiation detection/exposure assessment
4. Research needs for emerging hazards
5. Advantages/disadvantages of existing methods
6. Data management challenges
7. Specific NIOSH National Occupational Research Agenda (NORA) sector needs.

Information discussed during the radiation breakout session and is summerized in the rapport report form this session.

Surface Sampling

Day 1 – continued Surface Sampling/Biomonitoring

Session 6 – Surface Sampling/Biomonitoring
Monitors – John Snawder (NIOSH), Matthew Magnuson (EPA)
Speaker/Title of Presentation:

1. Biomonitoring:
    A. Michael Philips (Menssana Research, Inc. – To be determined
    B. Charles Timchalk, DABT (Pacific Northwest National Laboratory) – Nanotechnology-based Electrochemical Sensors for Biomonitoring Chemical Exposures
2. Surface Sampling:
    A. Jayne B. Morrow (National Institute of Standards and Technology) – To be determined
    B. Wassana Yantasee (Pacific Northwest National Laboratory) - Next-generation metal analyzers based on nanomaterials for biomonitoring and environmental monitoring
    C. Kevin Ashley (NIOSH) – Standardized Surface Sampling Methods for Metals

Rapporteur – Debbie Sammons (NIOSH)
Topics:

1. What is the role for NIOSH in addressing DRI/DRM issues?
2. Should NIOSH take the lead on a special DRI/DRM initiative?
3. Identification of stakeholders/users: level of involvement.
4. Types of DRI/DRM.
5. Current applications for DRI/DRM.
6. Obstacles to use of DRI/DRM.
7. Future applications/New Technologies.
8. Advantages/Disadvantages of particular instrumentation/methods.
9. Guidelines development: common criteria needed for multiple agencies.
10. Specific NIOSH National Occupational Research Agenda (NORA) sector needs.

BREATH TESTS FOR DISEASE AND TOXIC EXPOSURES

Michael Phillips MD, FACP

Menssana Research, Inc

and New York Medical College

Menssana Research, Inc

A VERY BRIEF HISTORY OF BREATH TESTING

Menssana Research, Inc

A VERY BRIEF HISTORY OF BREATH TESTING

Ancient Greece
Hippocrates - the "father of medicine"
Instructed students – smell your patient's breath!

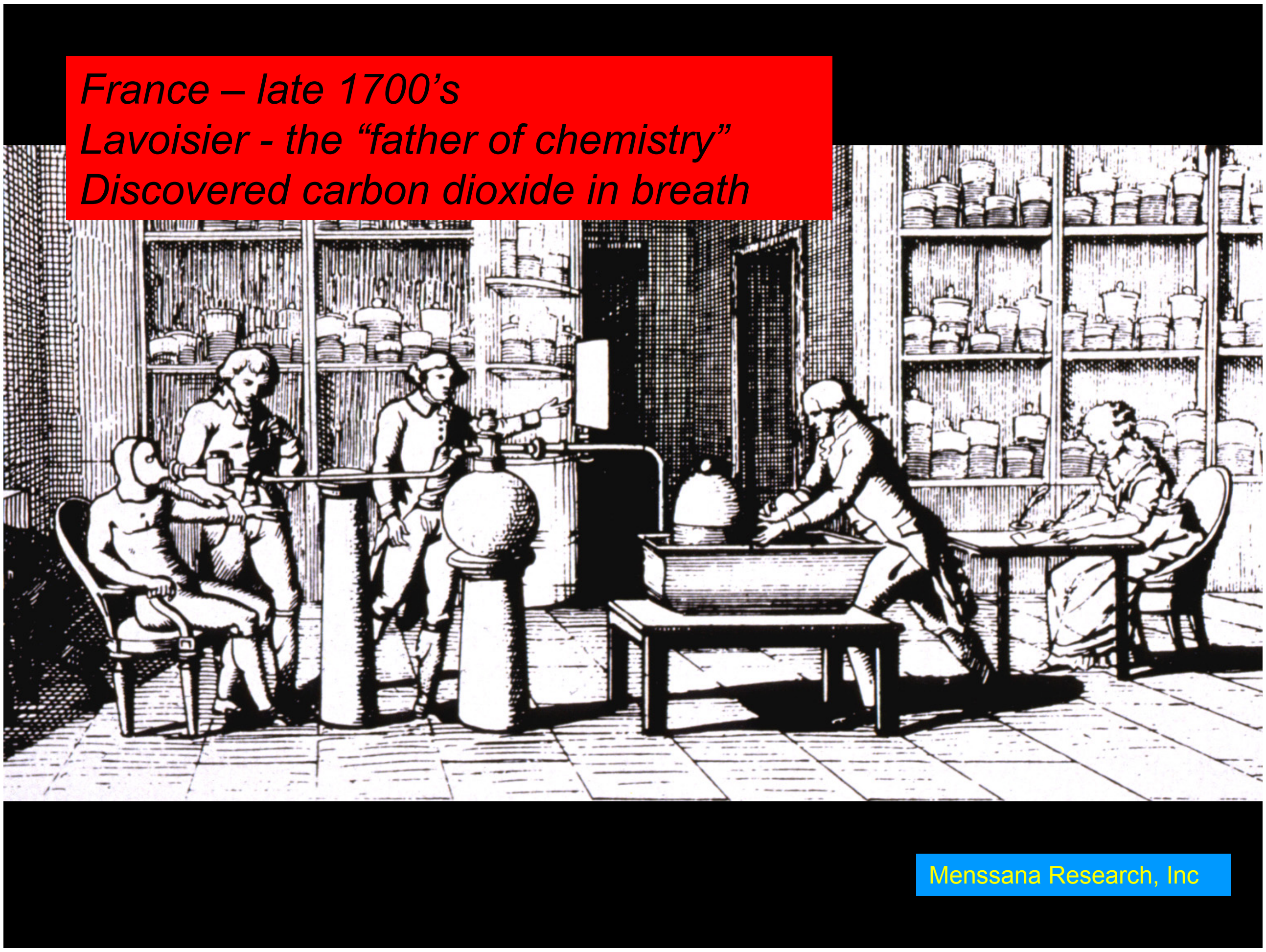
Menssana Research, Inc

A VERY BRIEF HISTORY OF BREATH TESTING

Ancient Greece
Hippocrates - the "father of medicine"
Instructed students – smell your patient's breath!

Diabetic ketoacidosis	*rotten apples*
Renal failure	*urine-like*
Liver failure	*fetor hepaticus*
Lung abscess	*sewer-like*
Nutrient recognition	*garlic, alcohol*

Menssana Research, Inc


France – late 1700's
Lavoisier - the "father of chemistry"
Discovered carbon dioxide in breath
Menssana Research, Inc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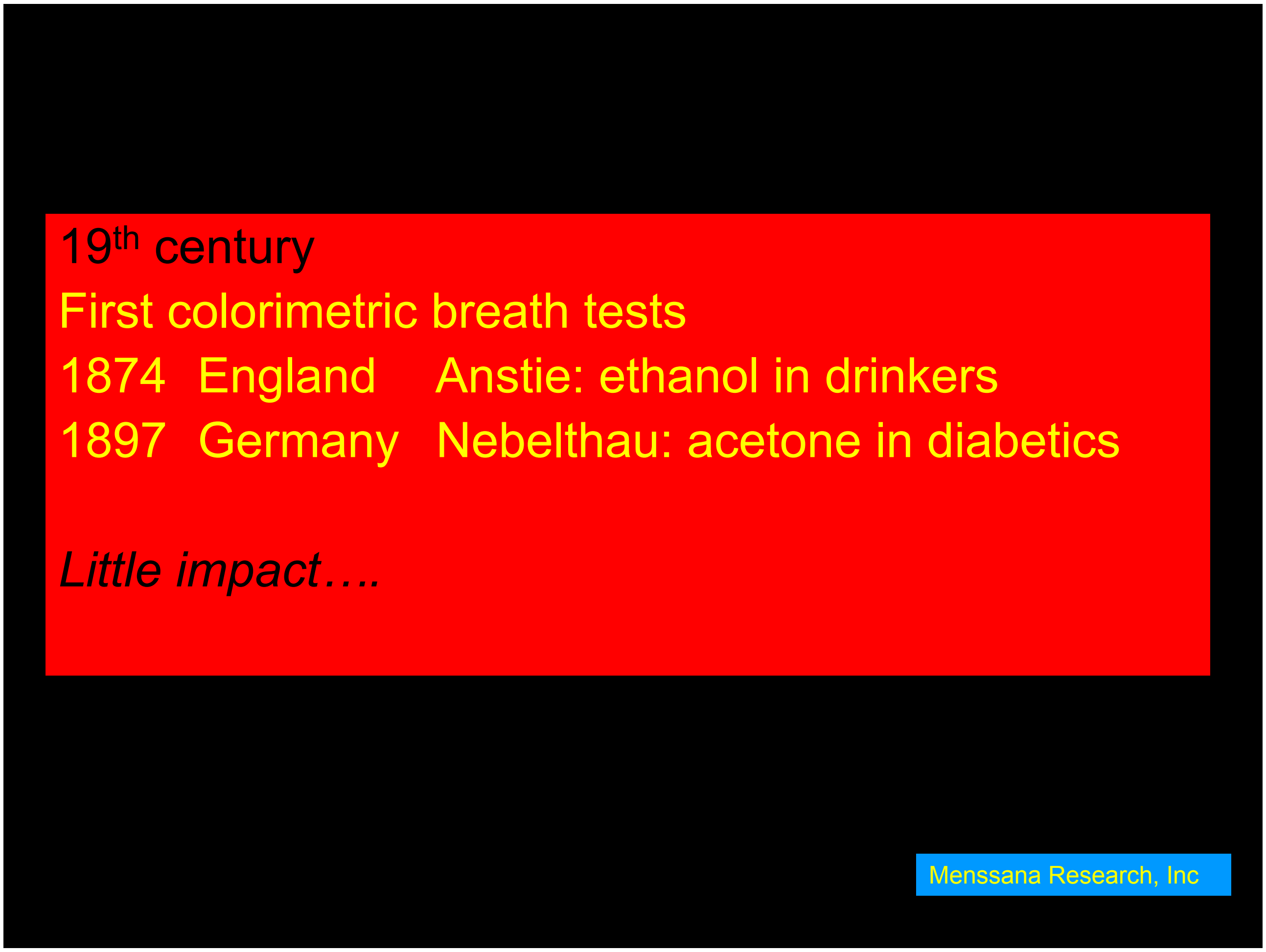

19th century
First colorimetric breath tests
1874 England Anstie: ethanol in drinkers
1897 Germany Nebelthau: acetone in diabetics
Little impact….
Menssana Research, Inc


…until 1950's, in USA
Menssana Research, Inc

1960's: Breath tests in gastroenterology

- Breath hydrogen and radiolabeled CO_2
- Diagnosis of

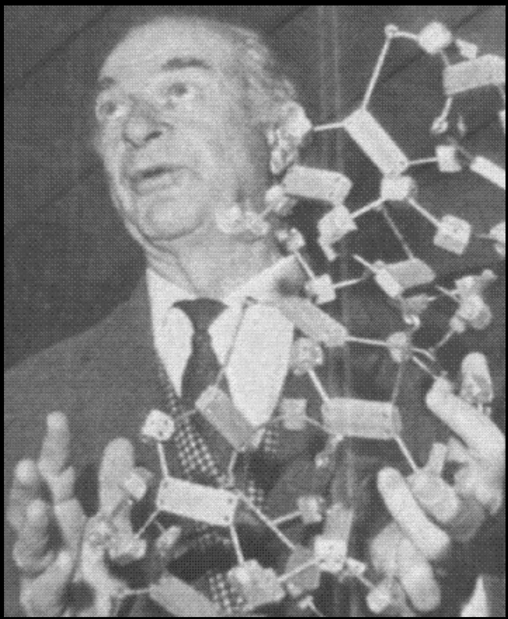
    malabsorption

    pancreatic disease

    liver disease

    bacterial overgrowth

Menssana Research, Inc



1971: USA

Linus Pauling

Two Nobel Prizes

AND

the first microanalysis of breath

Concentrated breath in a cold trap

→ GC analysis

→ discovered endogenous VOCs

Menssana Research, Inc

Advances in the past 20 years:

- *New applications – e.g. H. pylori UBT*
- *Improved technology*
  lab curiosity → clinical tool
- *Large clinical studies*
  → new biomarkers of disease

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BREATH TESTING: THE FOUR QUESTIONS

HOW?

WHAT?

WHY?

WHERE?

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BREATH TESTING: THE FOUR QUESTIONS

HOW do we analyze breath?

WHAT?

WHY?

WHERE?

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BREATH TESTING: THE FOUR QUESTIONS

HOW do we analyze breath?

WHAT do the results mean?

WHY?

WHERE?

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BREATH TESTING: THE FOUR QUESTIONS

HOW do we analyze breath?

WHAT do the results mean?

WHY do it?

WHERE?

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BREATH TESTING: THE FOUR QUESTIONS

HOW do we analyze breath?

WHAT do the results mean?

WHY do it?

WHERE is it leading?

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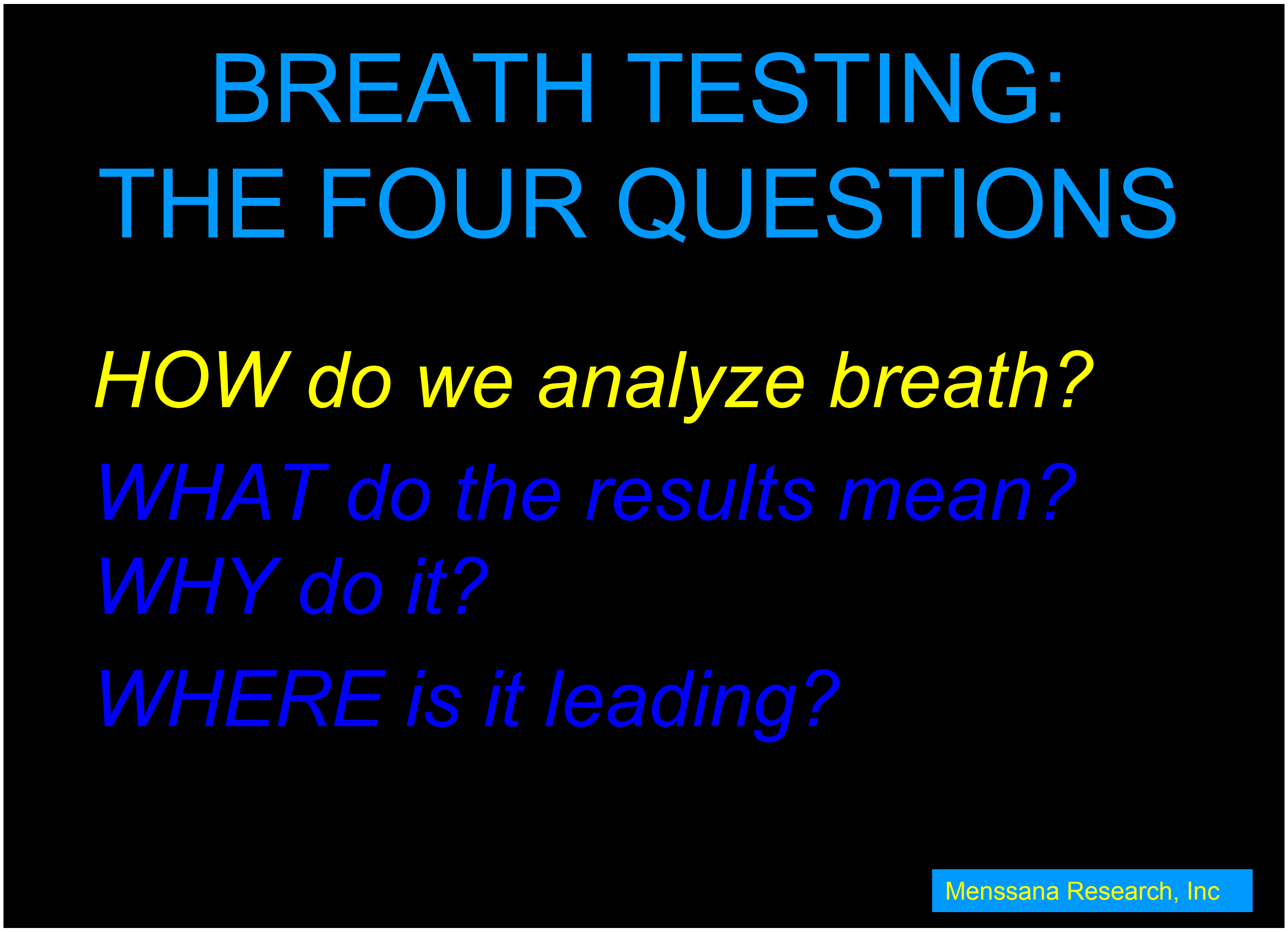
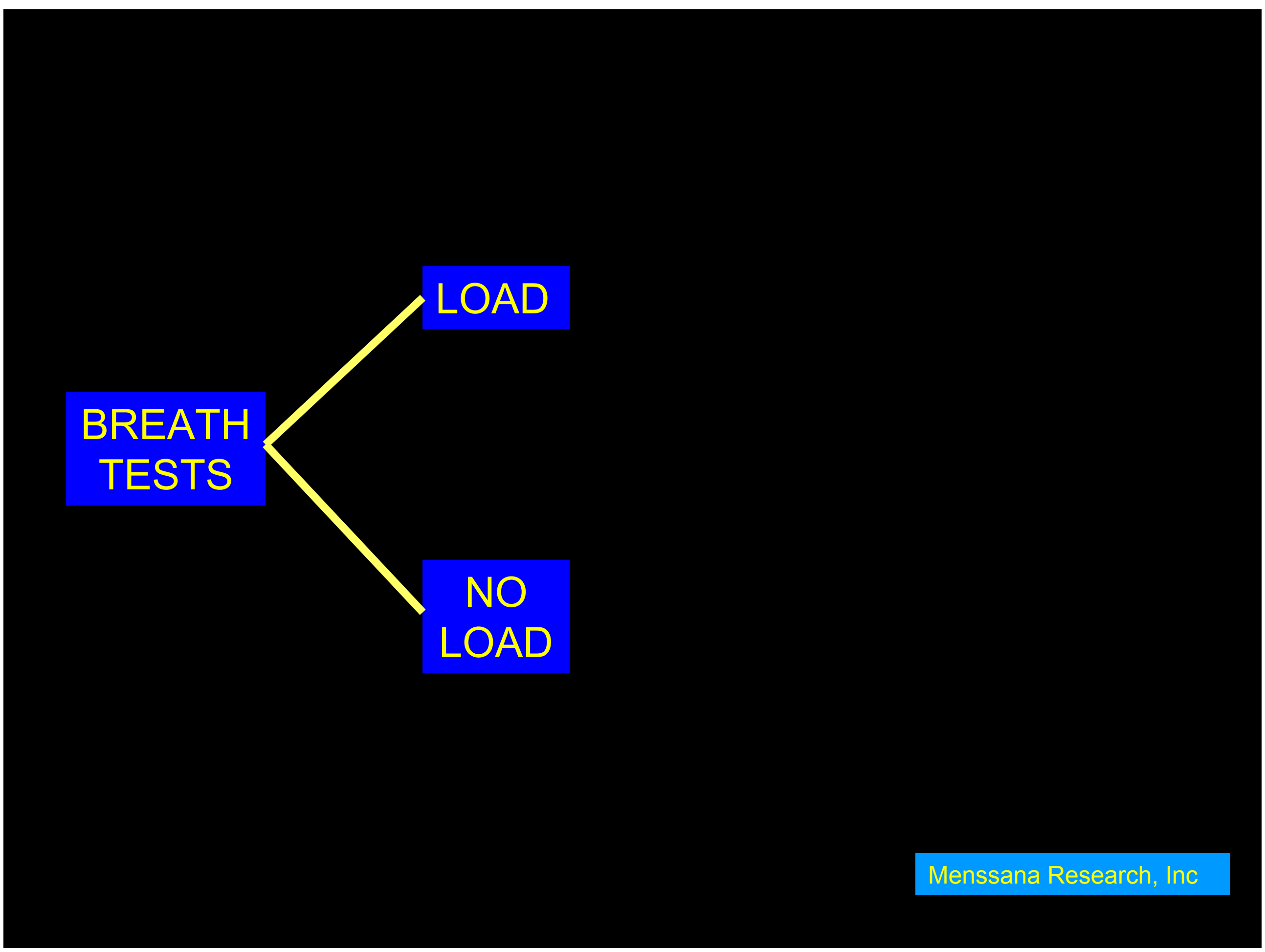
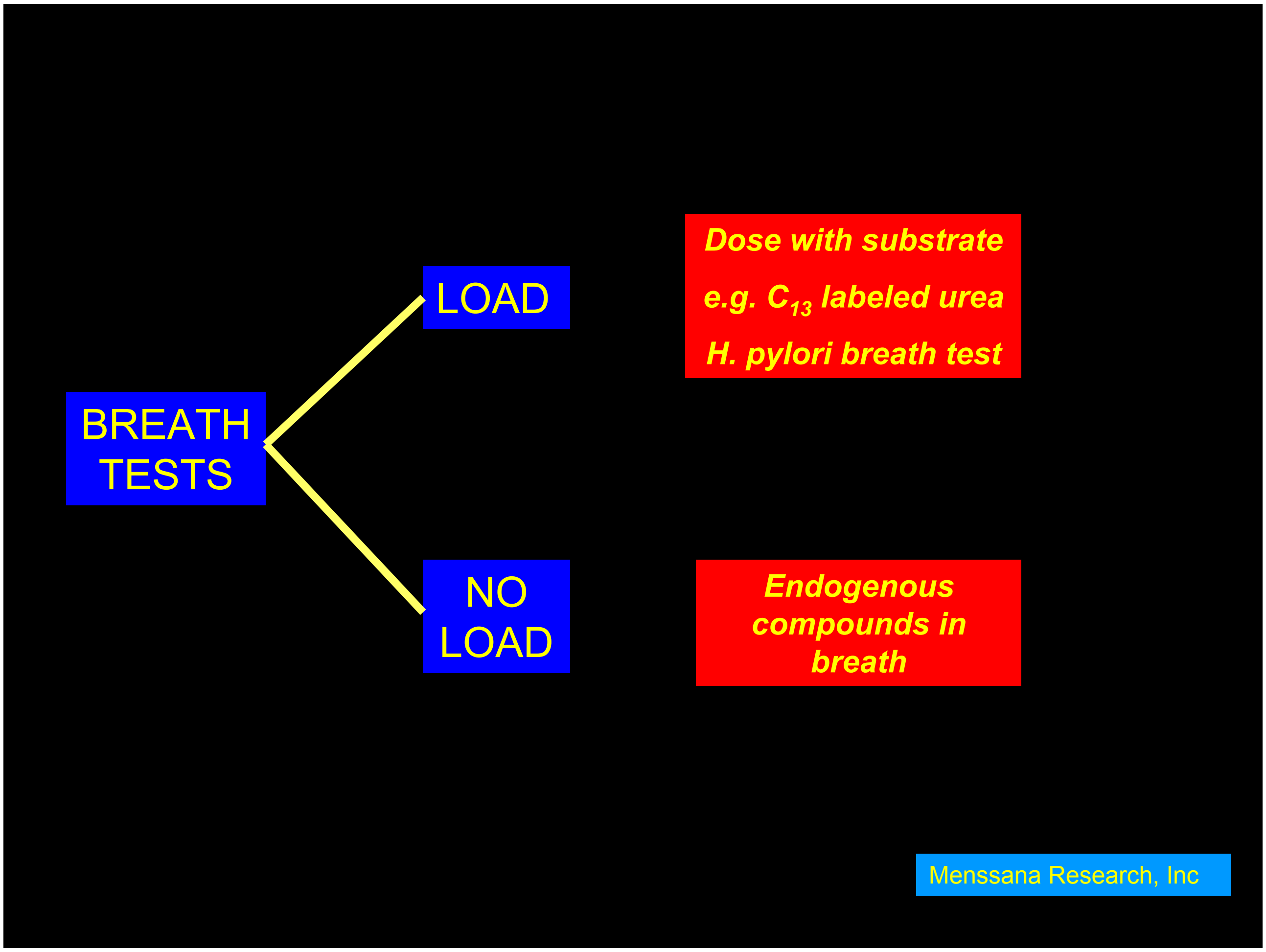
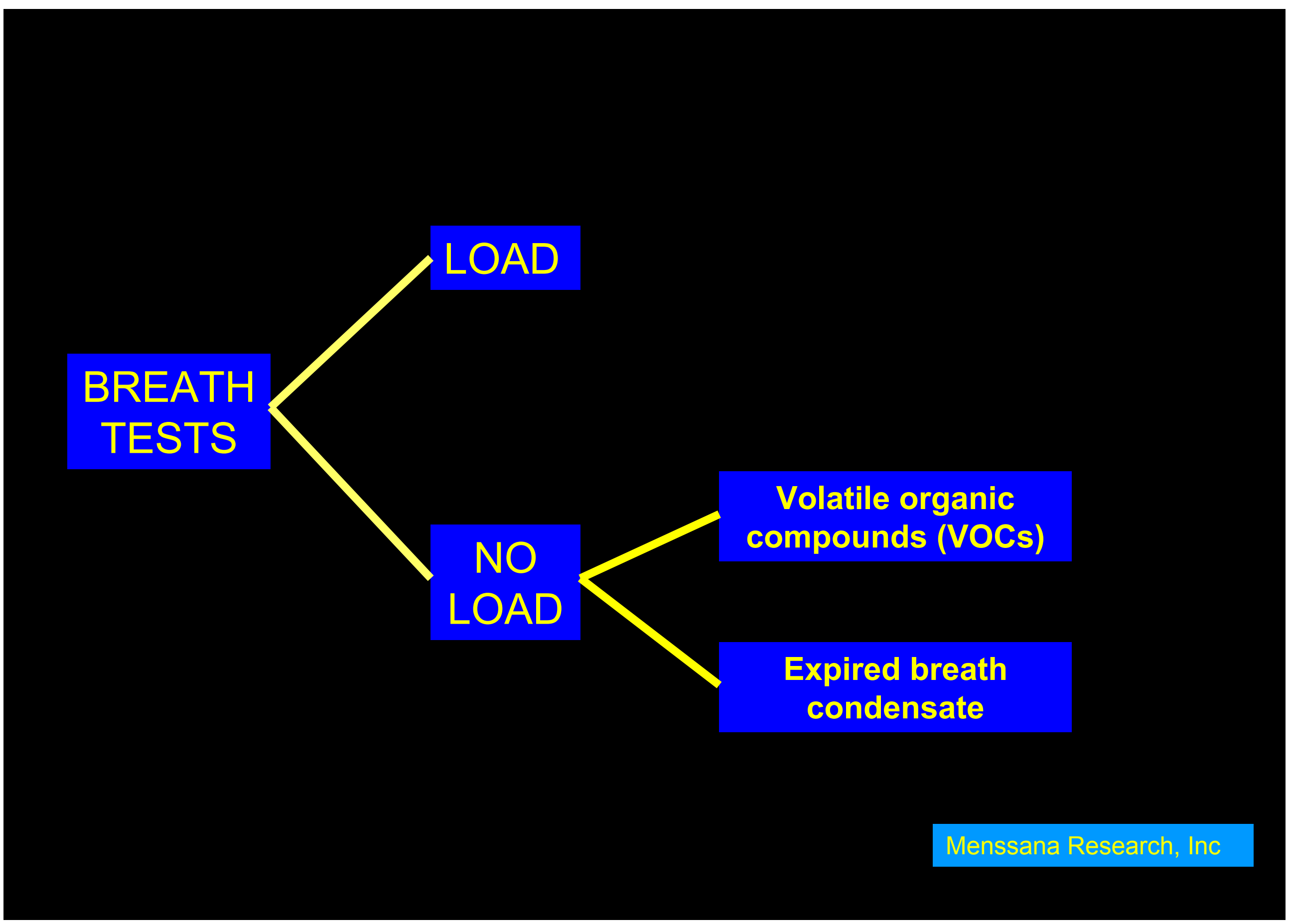
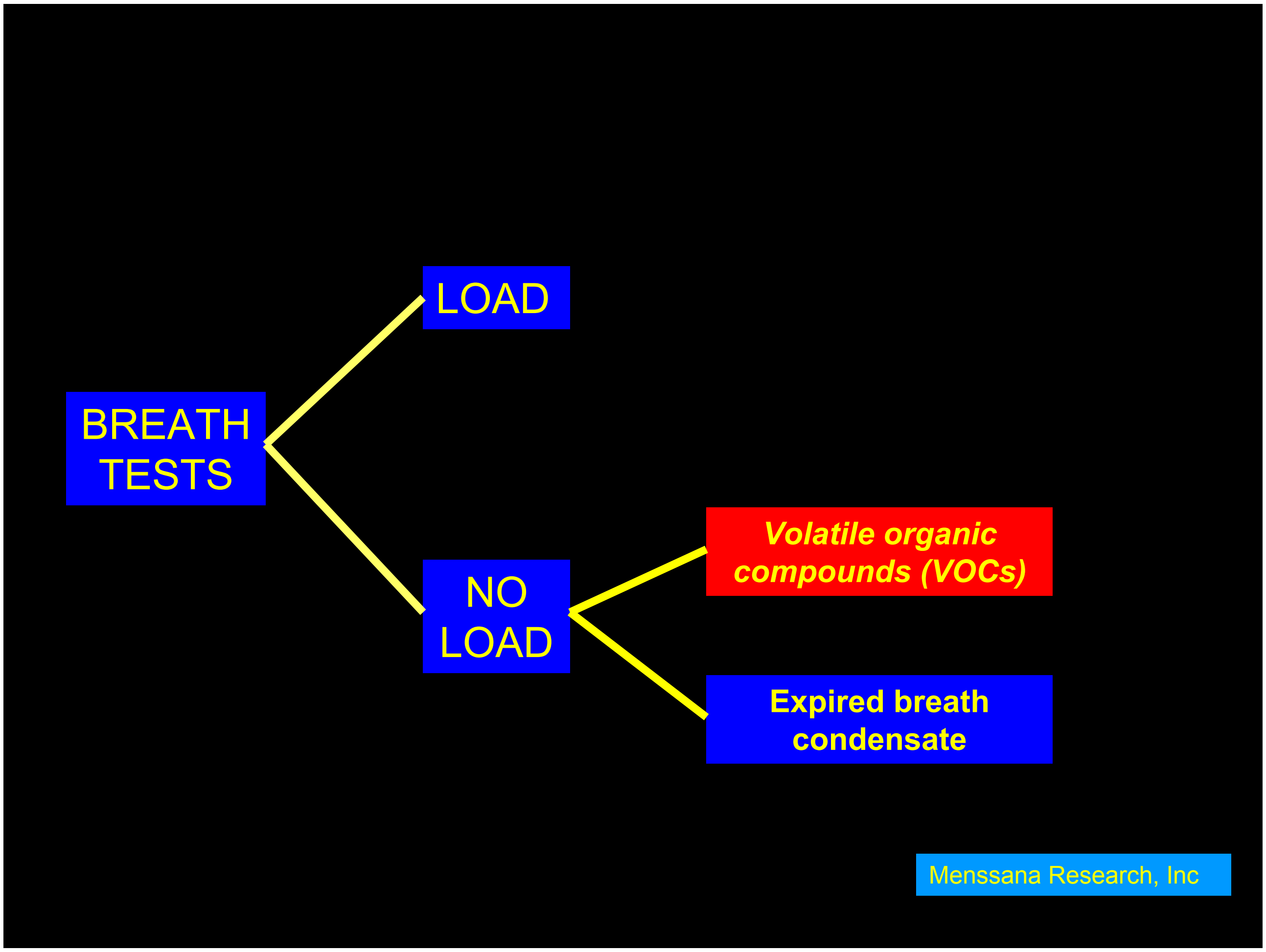
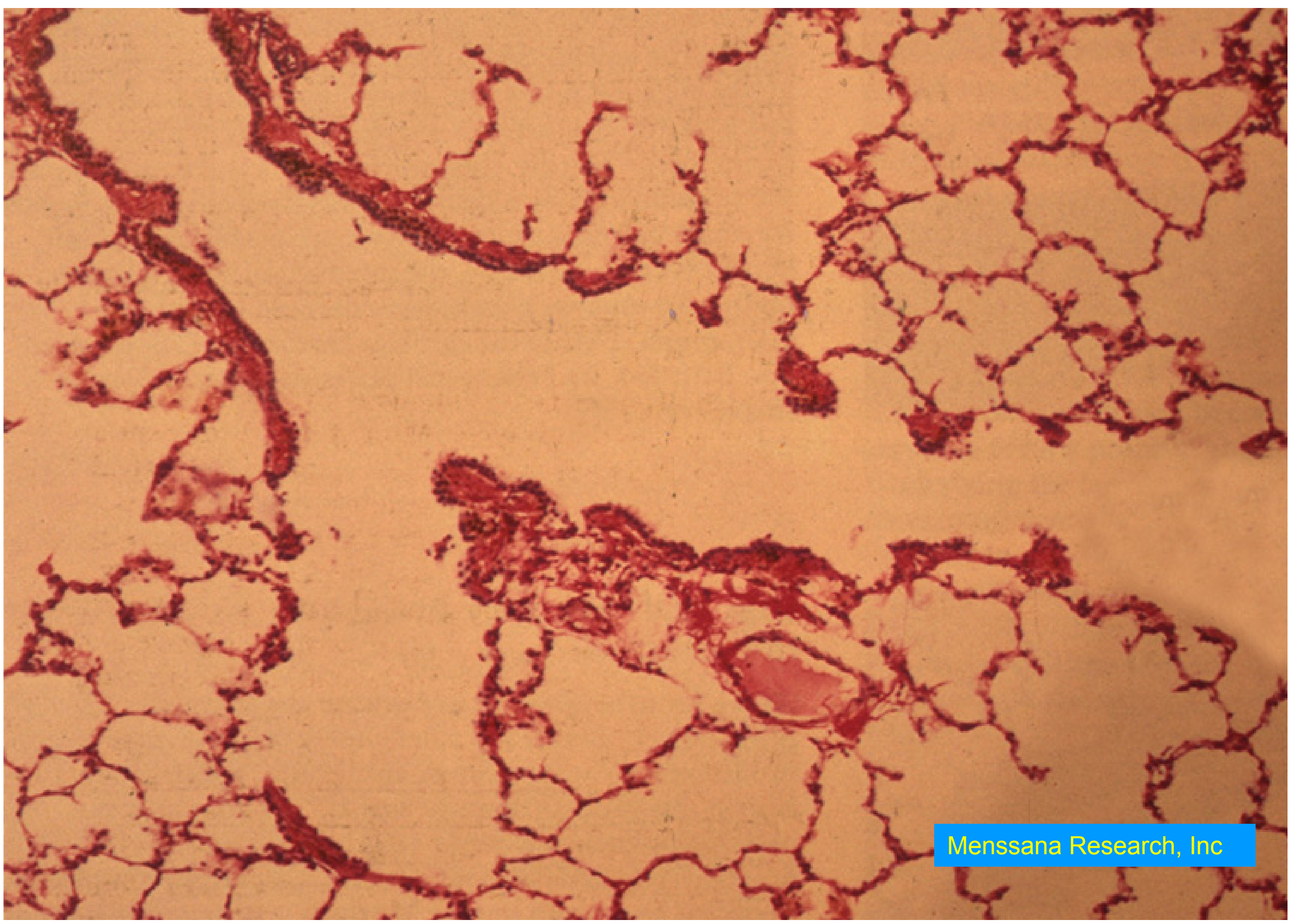

BREATH TESTING:
THE FOUR QUESTIONS
HOW do we analyze breath?
WHAT do the results mean?
WHY do it?
WHERE is it leading?
Menssana Research, Inc

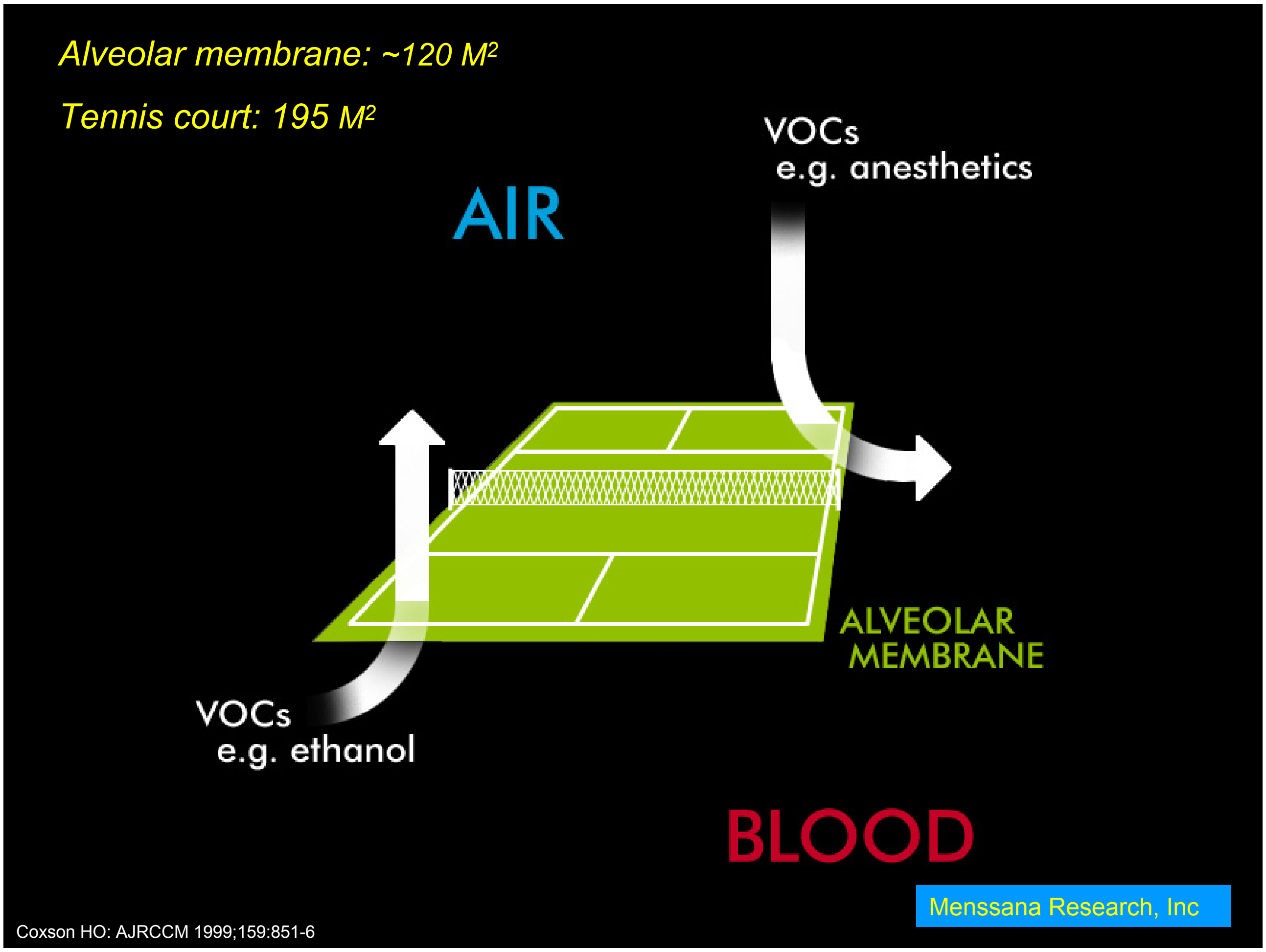

BREATH TESTS
LOAD
NO LOAD
Menssana Research, Inc

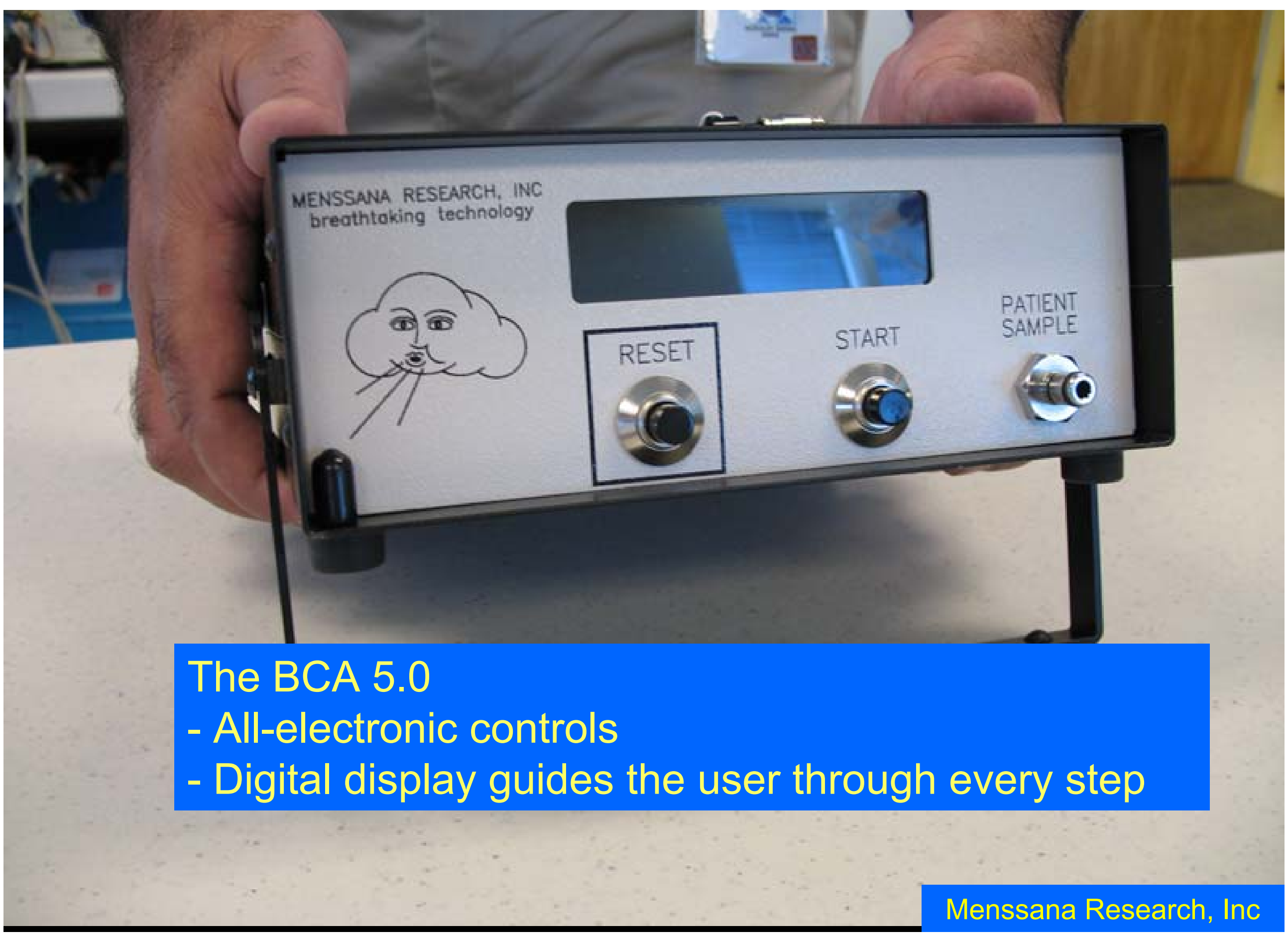

BREATH TESTS
LOAD
NO LOAD
Dose with substrate
e.g. C_{13} labeled urea
H. pylori breath test
Endogenous compounds in breath
Menssana Research, Inc

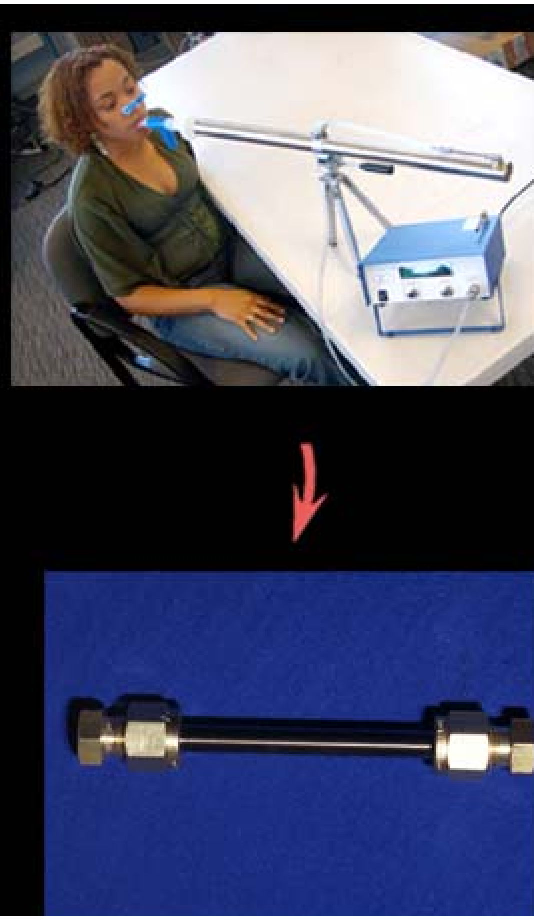

BREATH TESTS
LOAD
NO LOAD
Volatile organic compounds (VOCs)
Expired breath condensate
Menssana Research, Inc

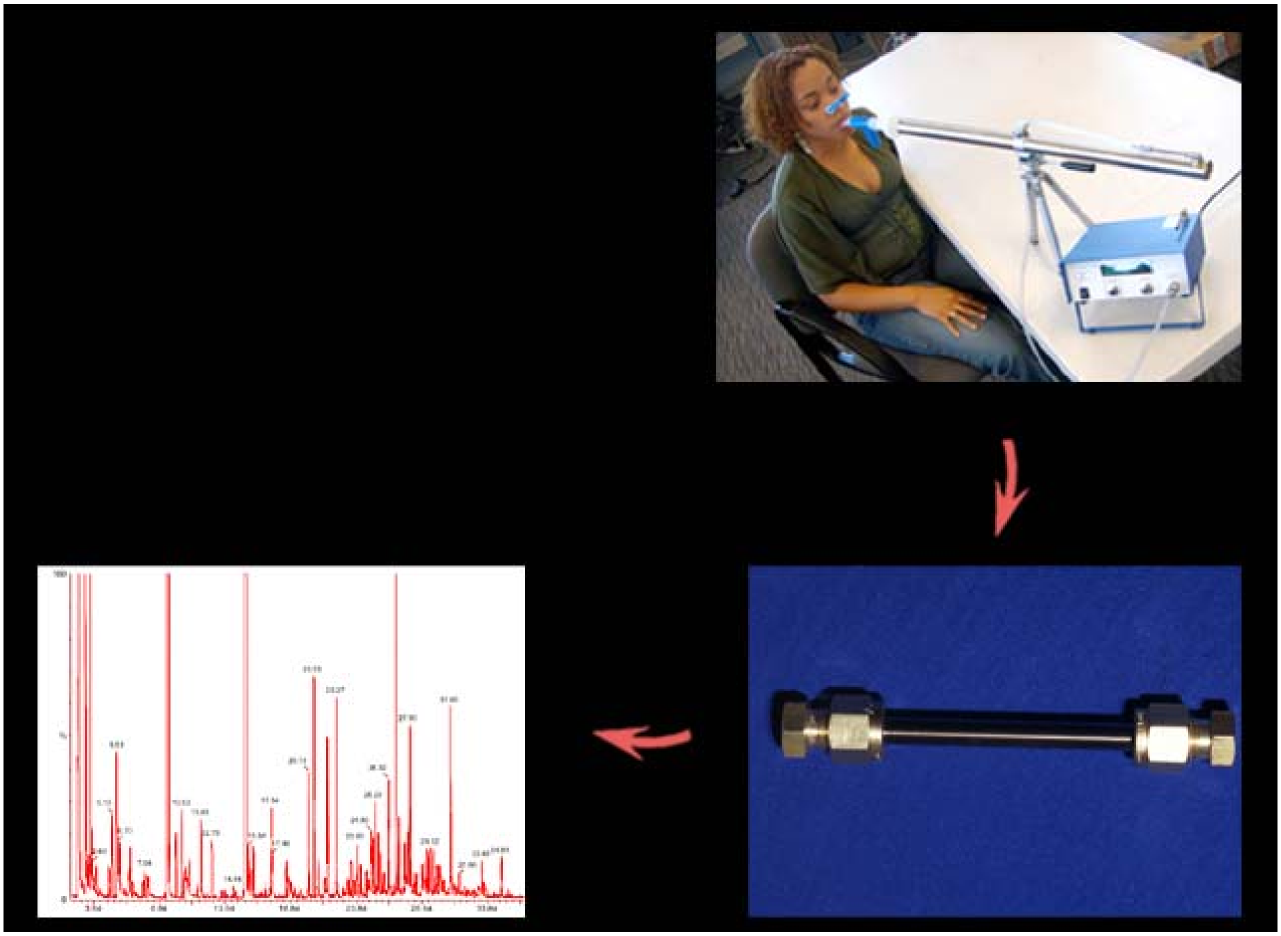

LOAD
BREATH TESTS
Volatile organic compounds (VOCs)
NO LOAD
Expired breath condensate
Menssana Research, Inc

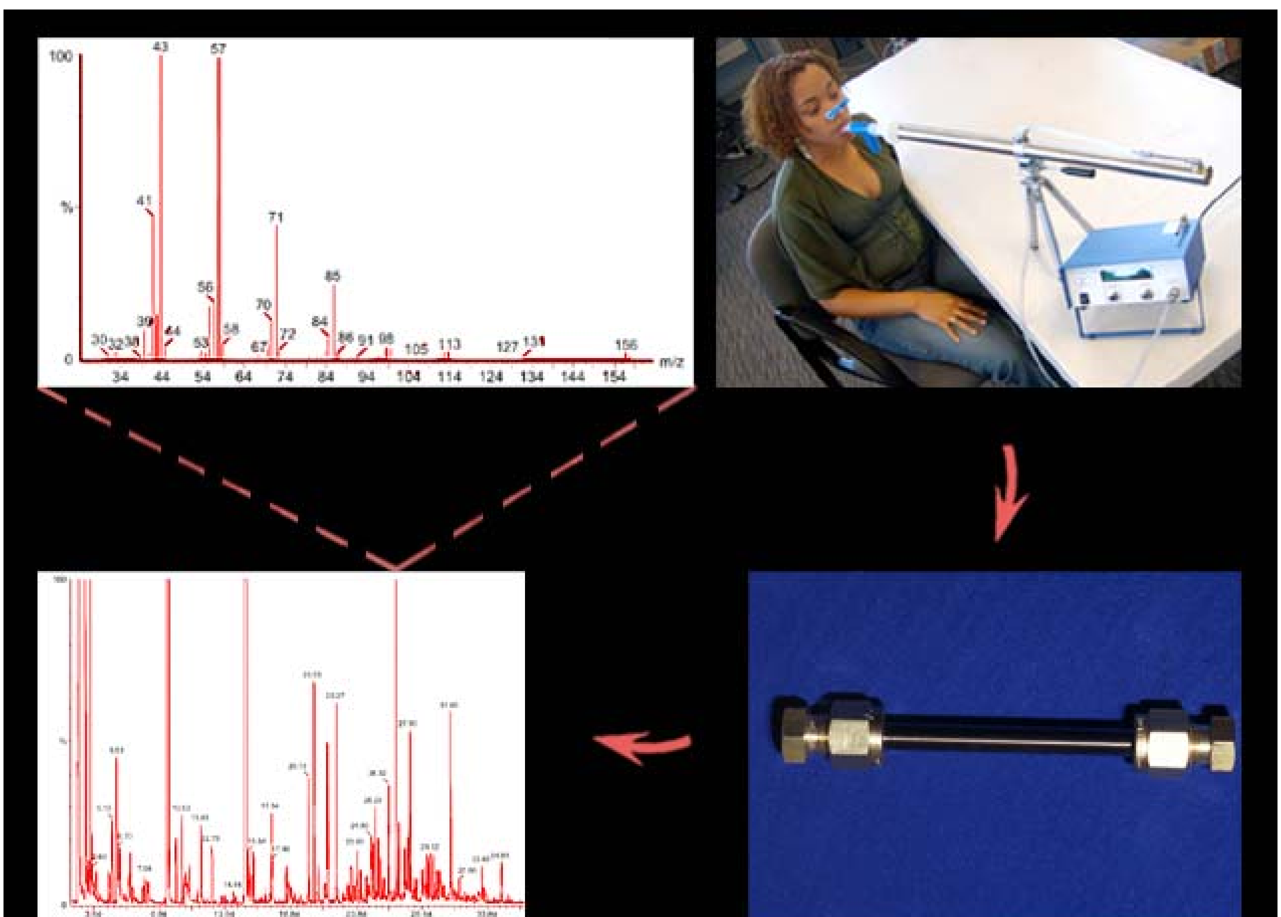

Menssana Research, Inc


Alveolar membrane: ~120 M2
Tennis court: 195 M2
VOCs
e.g. anesthetics
AIR
ALVEOLAR
MEMBRANE
VOCs
e.g. ethanol
BLOOD
Menssana Research, Inc
Coxson HO: AJRCCM 1999;159:851-6


MENSSANA RESEARCH, INC
breathtaking technology
RESET
START
PATIENT
SAMPLE
The BCA 5.0
- All-electronic controls
- Digital display guides the user through every step
Menssana Research, Inc






100
%
0
43
57
41
71
85
56
70
39
44
58
84
72
53
30
32
38
67
86
91
98
105
113
127
131
156
m/z
34
44
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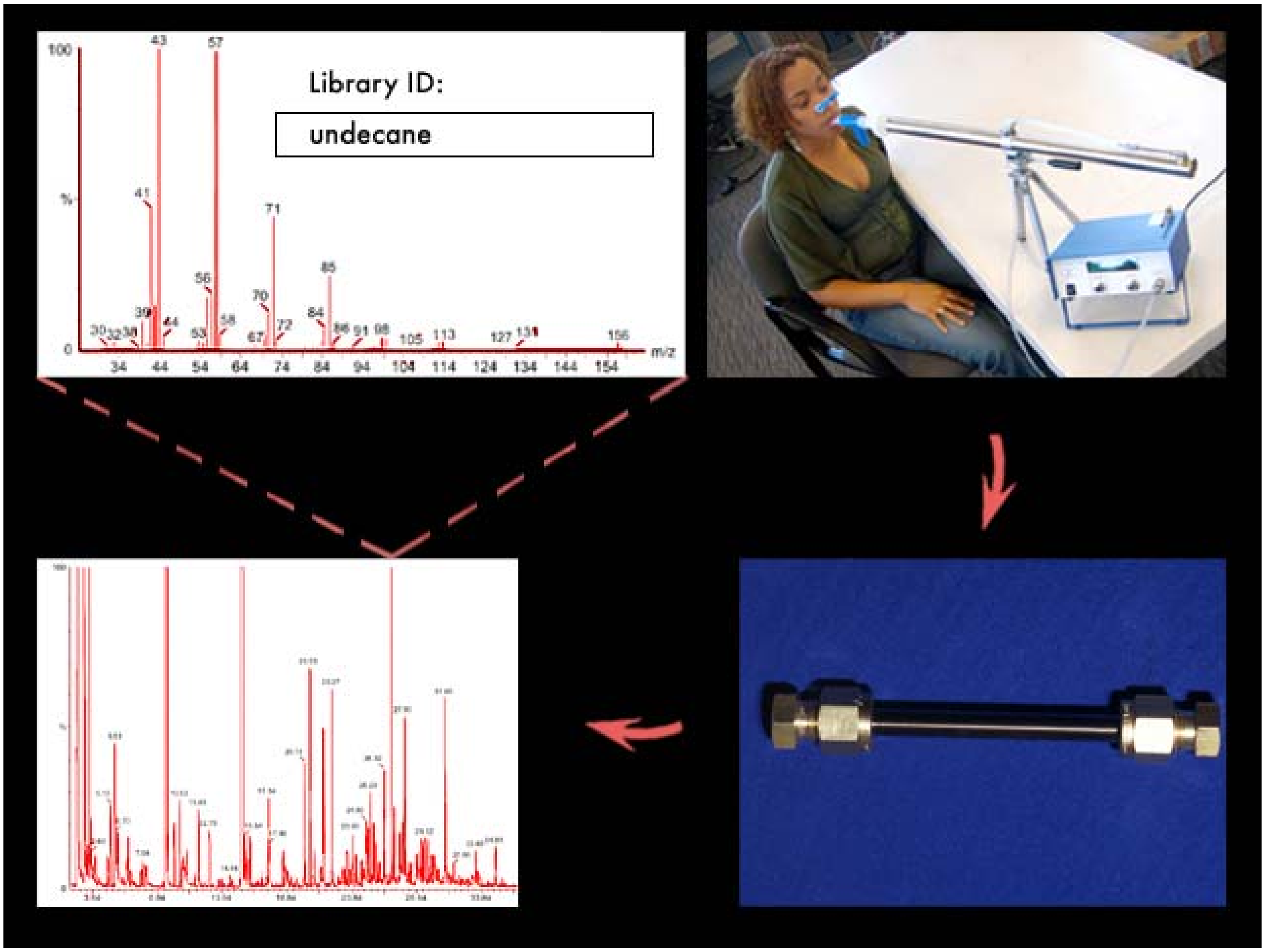
64
74
84
94
104
114
124
134
144
154



	C:\HPCHE	Norm. Hum. Study, Breath 1, Tube #173		
	RT	VOC	Area	Quality
1	1.76112	Butane	1.47E+06	49
2	2.0959	Ethanol	219710	86
3	2.19635	Butane, 2-methyl-	2.00E+06	91
4	2.39722	2-Propanone	6.18E+06	86
5	2.58135	1,3-Butadiene, 2-methyl-	2.14E+07	93
6	2.76548	1-Butene, 2-methyl-	998209	91
7	2.86592	1,2-Pentadiene	208507	86
8	2.93288	Ethane, 1,1,2-trichloro-1,2,2-trifluoro-	183187	43
9	3.08353	2,3-Pentadiene	105270	93
10	3.3681	Cyclopentene	156352	91
11	3.4518	Pentane, 3-methylene-	87692	70
12	3.56898	Butane, 2,3-dimethyl-	404068	78
13	3.71963	Pentane, 2-methyl-	1.48E+06	87
14	3.82007	Propane, 2-methoxy-2-methyl-	2.72E+06	42
15	4.12138	Pentane, 3-methyl-	1.04E+06	87
16	4.42268	1-Pentene, 2-methyl-	428950	83
17	4.75748	Hexane	998527	91
18	4.94162	Furan, 2-methyl-	683458	90
19	5.09228	2-Hexene, (E)-	270476	91
20	5.17597	2-Pentene, 2-methyl-	995042	80
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
192	51.4271	Octadecane	110167	90
193	51.695	2-(Methylamino)anthraquinone	41043	11
194	51.9963	Heptacosane	845932	99
195	52.4482	Octacosane	172853	91
196	52.5487	Nonadecane, 9-methyl-	207177	93
197	52.6826	AZADIBENZOPYRENE	50624	56
198	52.9169	1,2-Benzenedicarboxylic acid, bis(2-ethy	70140	68

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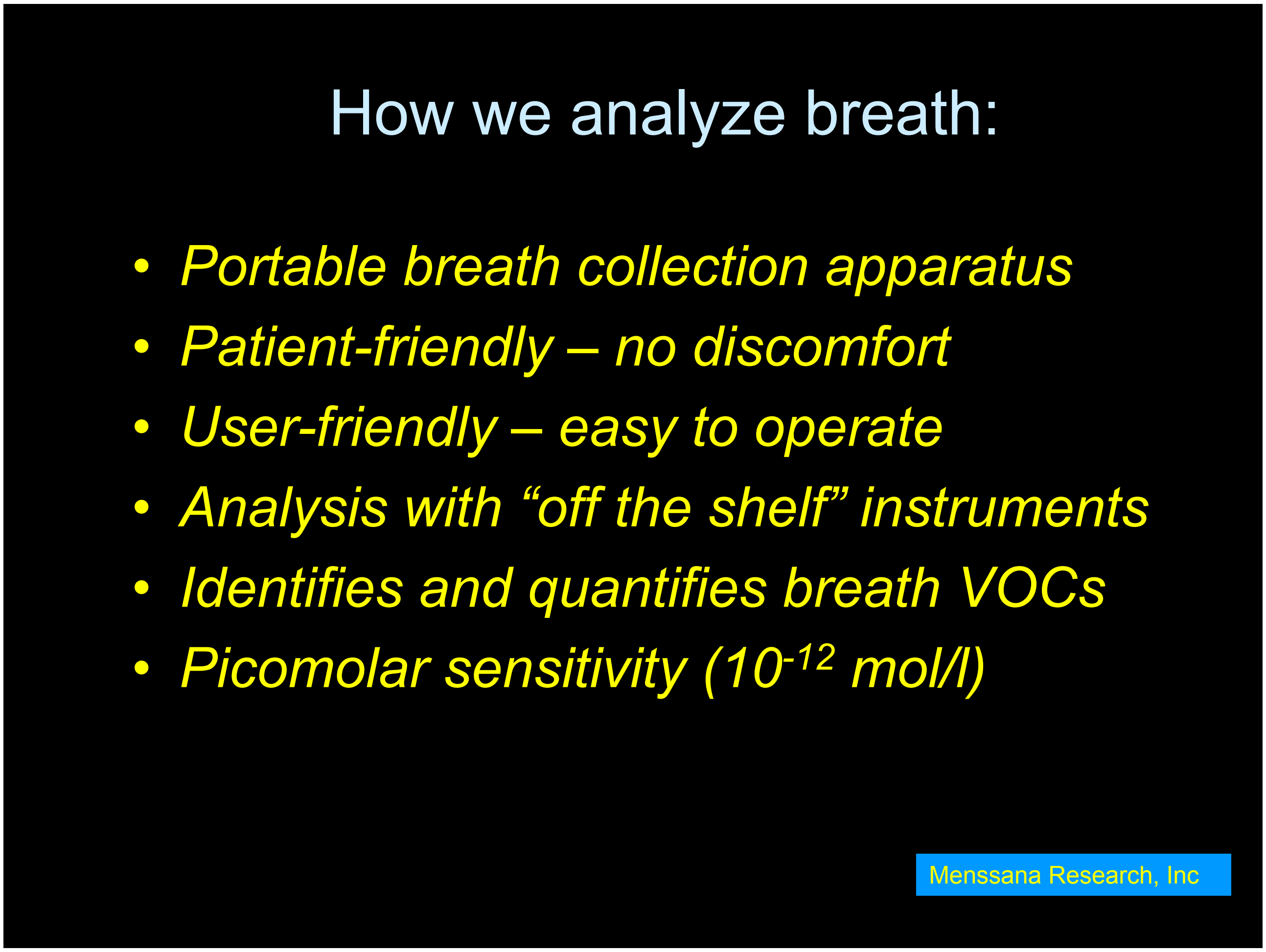
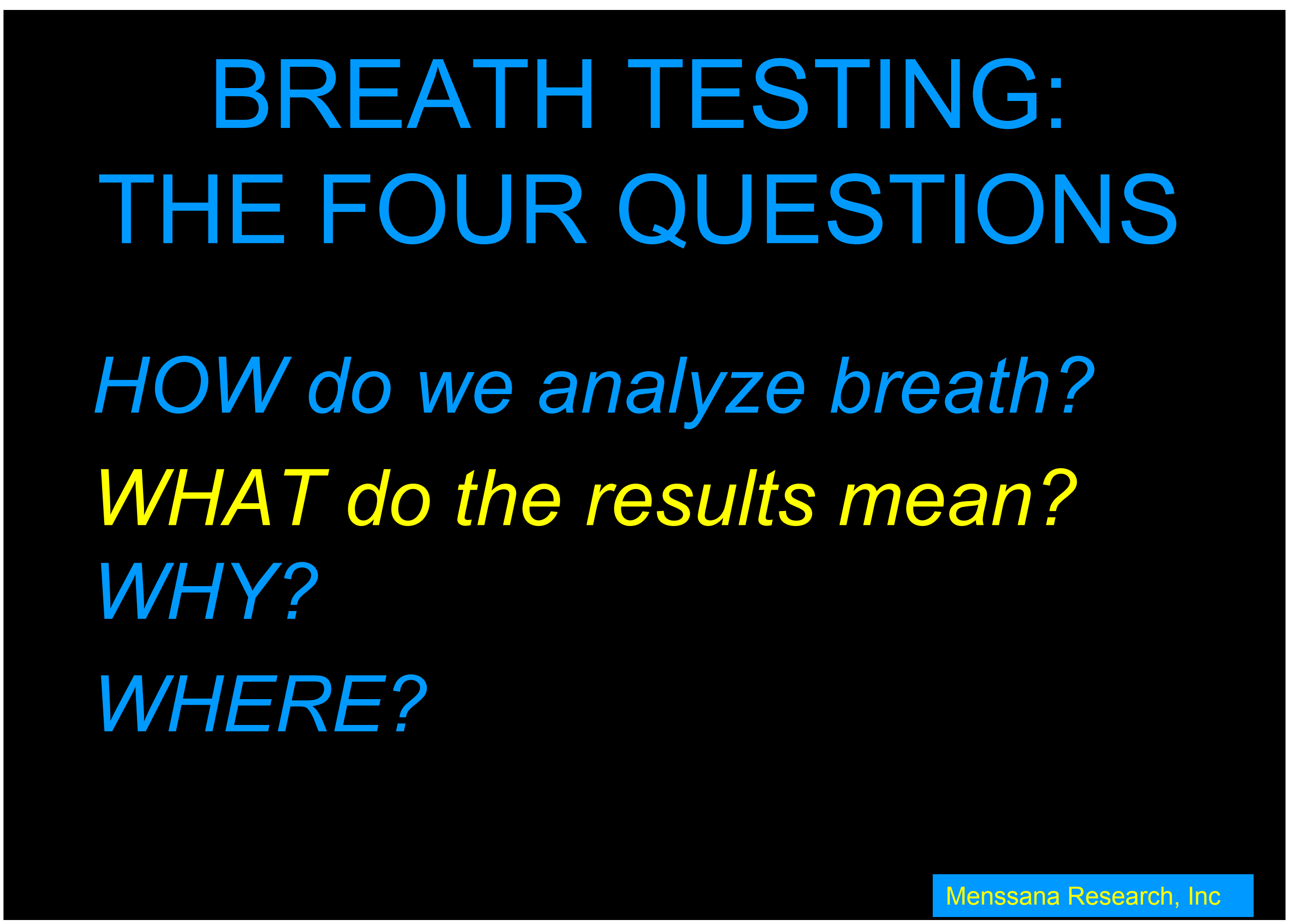

How we analyze breath:
• Portable breath collection apparatus
• Patient-friendly – no discomfort
• User-friendly – easy to operate
• Analysis with "off the shelf" instruments
• Identifies and quantifies breath VOCs
• Picomolar sensitivity (10^{-12} mol/l)
Menssana Research, Inc


BREATH TESTING:
THE FOUR QUESTIONS
HOW do we analyze breath?
WHAT do the results mean?
WHY?
WHERE?
Menssana Research, Inc

THE BACKGROUND AIR PROBLEM

Improved technology revealed:

Most breath VOCs are also present in room air!

Are breath VOCs recycled room air VOCs?

Options

1. Ignore the problem
2. Supply patient with ultra-pure air
3. Subtract air background from breath

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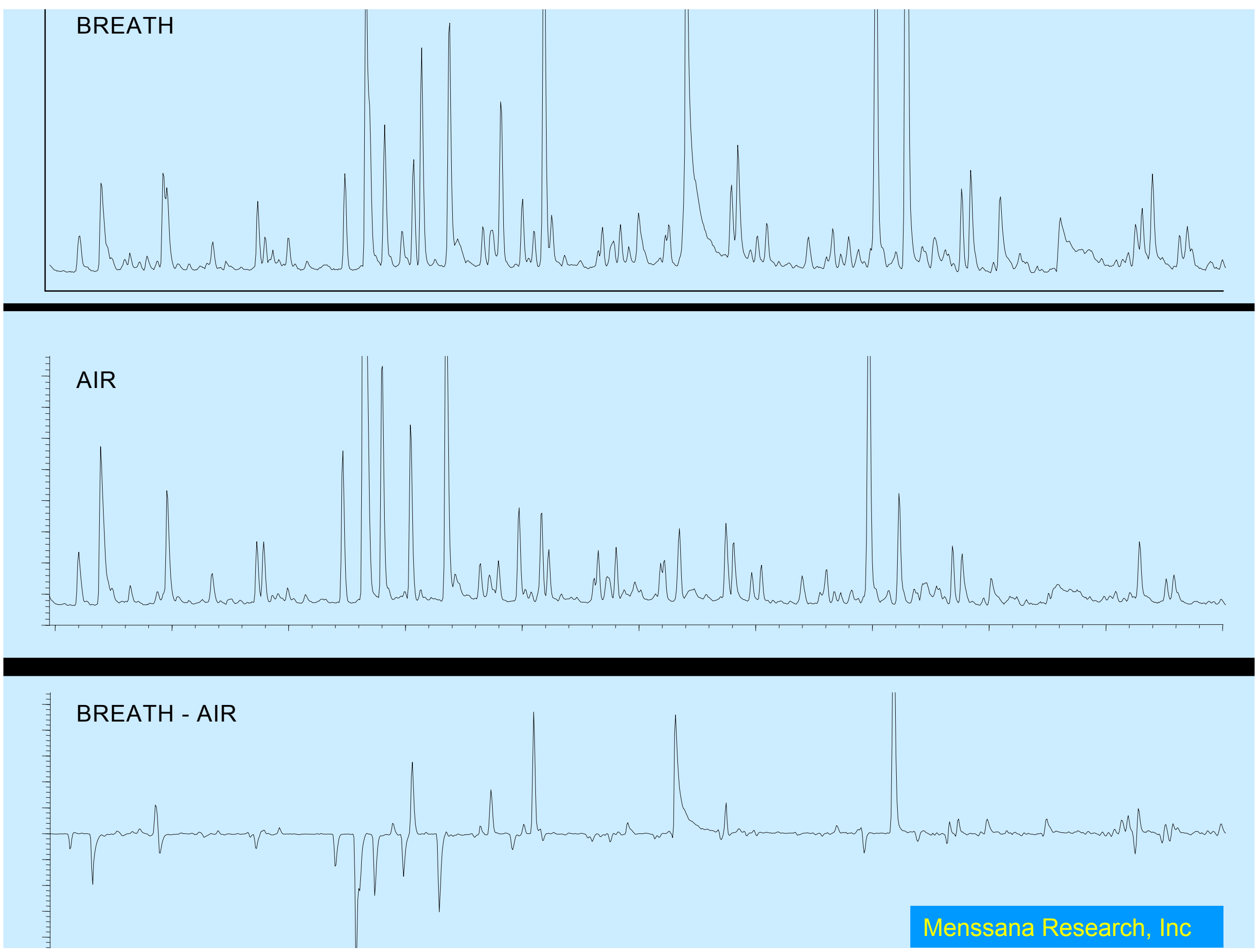


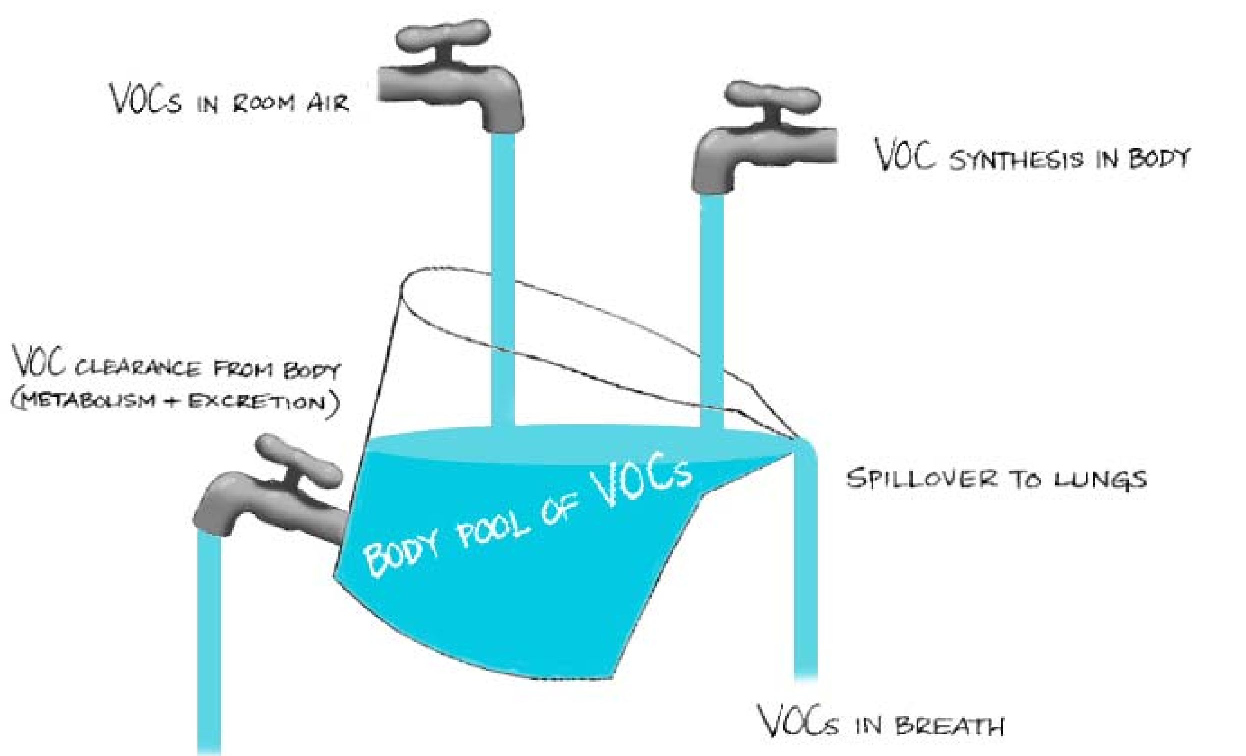
THE ALVEOLAR GRADIENT

$= \text{Concentration}_{\text{breath}} - \text{Concentration}_{\text{room air}}$

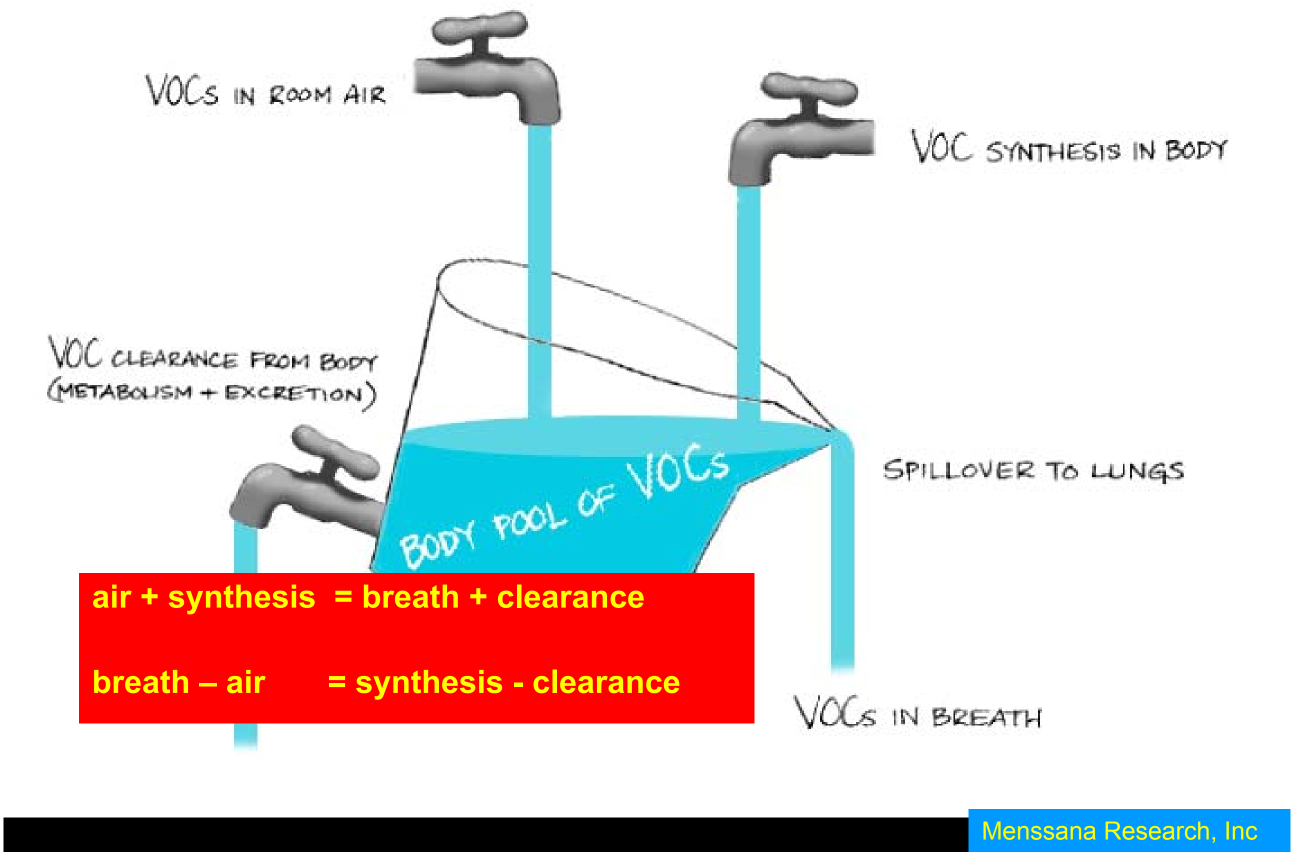
varies with: $\text{Rate}_{\text{synthesis}} - \text{Rate}_{\text{clearance}}$

Phillips et al: J Chromatogr B Biomed Sci Appl 1999; 729: 75-88

Menssana Research, Inc



Menssana Research, Inc



WHAT ARE THE VOCs IN NORMAL HUMAN BREATH?

Study

Breath tests in 50 fasting normal humans

Results

VOCs in each person	app. 200
Total different VOCs	3481
Positive alveolar gradient	1753
Negative alveolar gradient	1728

Phillips et al: J Chromatogr B Biomed Sci Appl 1999; 729: 75-88

Menssana Research, Inc

WHAT ARE THE VOCs IN NORMAL HUMAN BREATH?

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Results

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Positive alveolar gradient	1753
Negative alveolar gradient	1728

PROBLEM! TOO MUCH DATA!

Menssana Research, Inc

WHAT ARE THE VOCs IN NORMAL HUMAN BREATH?

Study

Breath tests in 50 fasting normal humans

Results

VOCs in each person	app. 200
Total different VOCs	3481
Positive alveolar gradient	1753
Negative alveolar gradient	1728
Common core VOCs	27

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COMMON CORE VOCs

GRADIENT POSITIVE

isoprene
benzene, 1-methylethenyl
naphthalene
cyclohexadiene
naphthalene, 1-methyl
butane, 2-methyl
tetradecane
pentadecane
dodecane

GRADIENT NEGATIVE

benzene
benzene, 1-ethyl-2-methyl
benzene, ethyl
benzene, methyl
benzene, propyl
cyclohexane, methyl
decane
heptane
heptane, 2-methyl
heptane, 3-methyl
hexane
hexane, 3-methyl
nonane
pentane, 2,3,4-trimethyl
pentane, 2-methyl
pentane, 3-methyl
propane, 2-methoxy-2-methyl
undecane

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COMMON CORE VOCs

GRADIENT POSITIVE

isoprene
benzene, 1-methylethenyl
naphthalene
cyclohexadiene
naphthalene, 1-methyl
butane, 2-methyl
tetradecane
pentadecane
dodecane

GRADIENT NEGATIVE

benzene
benzene, 1-ethyl-2-methyl
benzene, ethyl
benzene, methyl
benzene, propyl
cyclohexane, methyl
decane
heptane
heptane, 2-methyl
heptane, 3-methyl
hexane
hexane, 3-methyl
nonane
pentane, 2,3,4-trimethyl
pentane, 2-methyl
pentane, 3-methyl
propane, 2-methoxy-2-methyl
undecane

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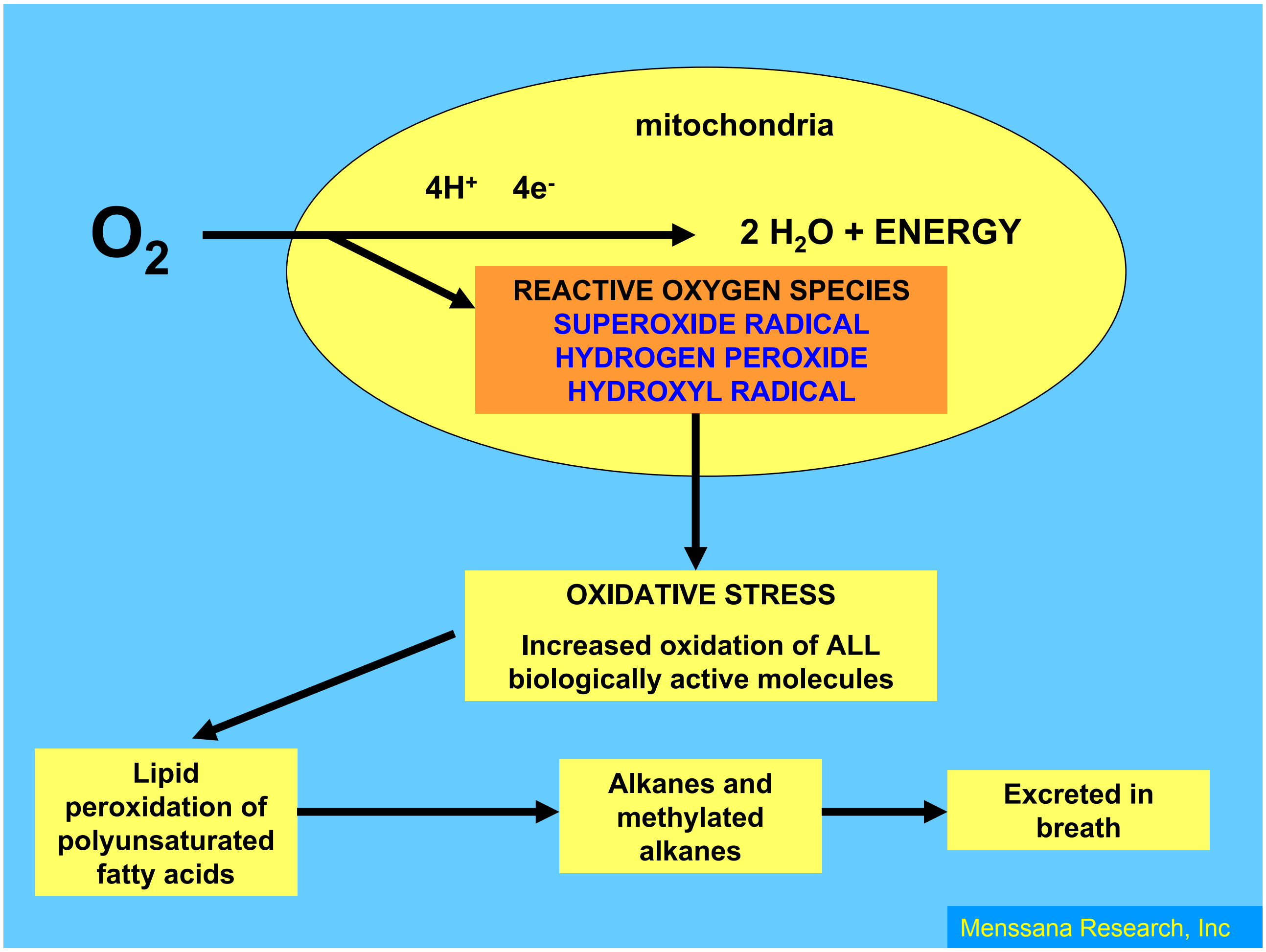
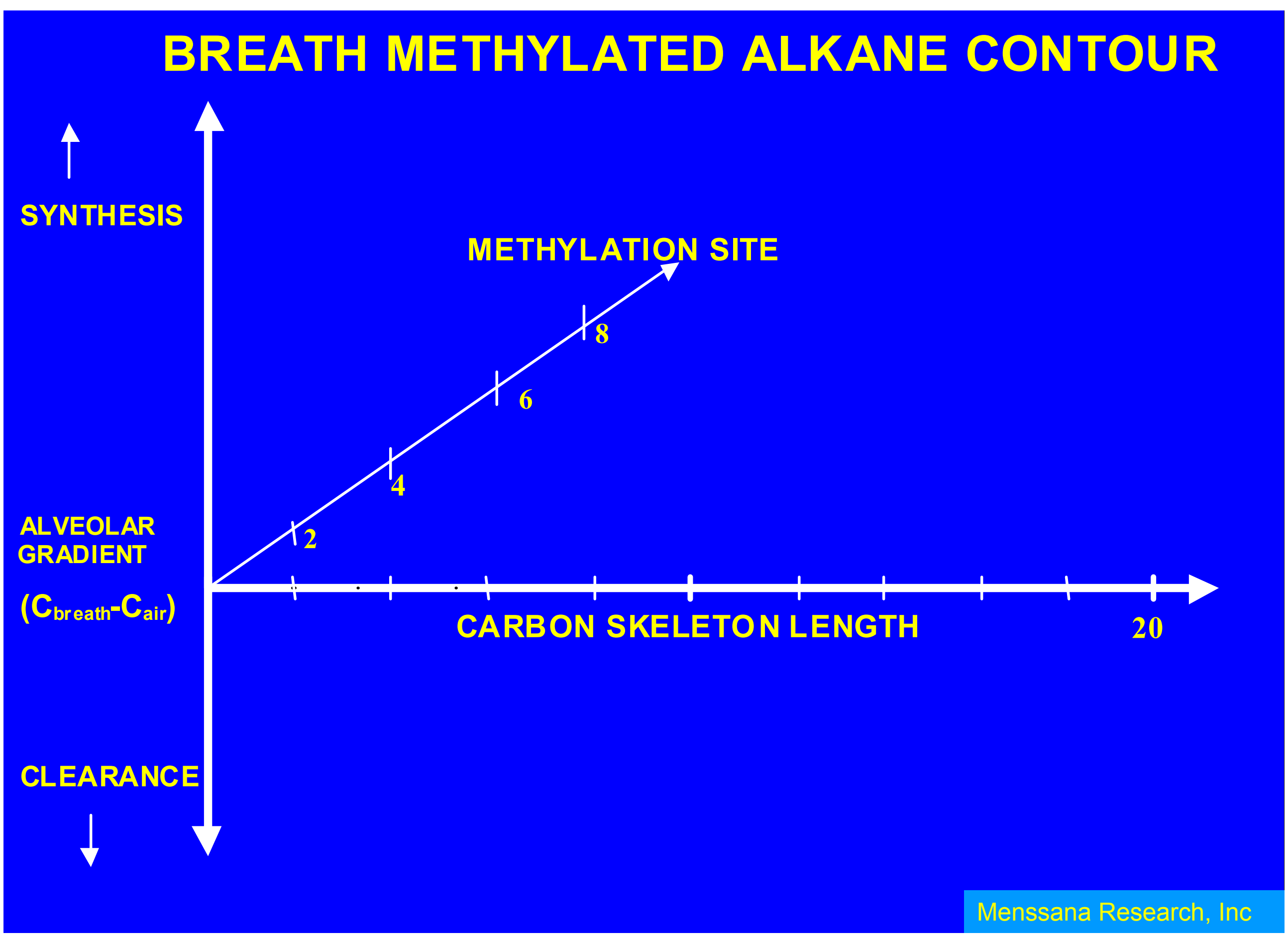
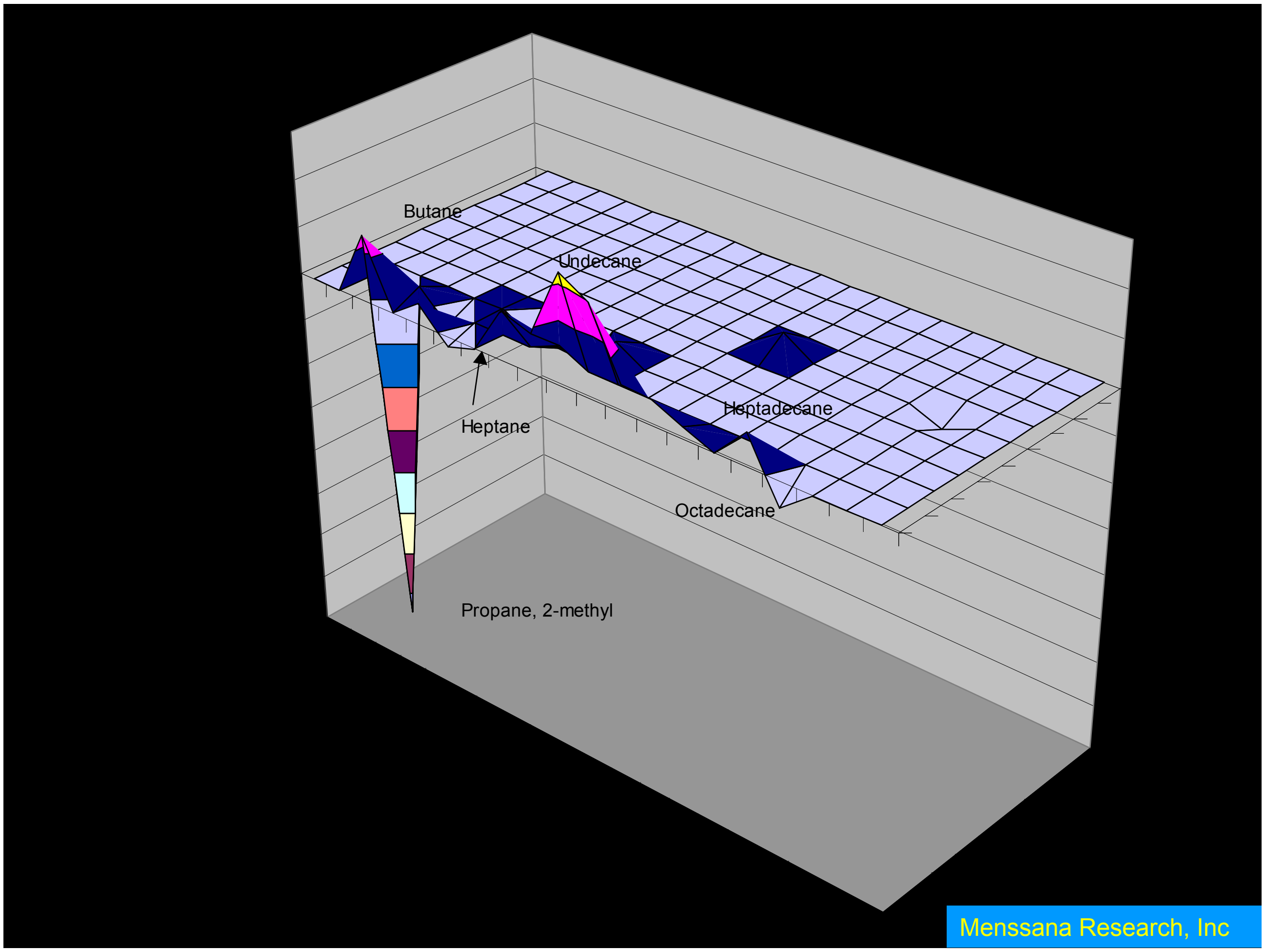

mitochondria
4H+ 4e-
O2
2 H2O + ENERGY
REACTIVE OXYGEN SPECIES
SUPEROXIDE RADICAL
HYDROGEN PEROXIDE
HYDROXYL RADICAL
OXIDATIVE STRESS
Increased oxidation of ALL biologically active molecules
Lipid peroxidation of polyunsaturated fatty acids
Alkanes and methylated alkanes
Excreted in breath
Menssana Research, Inc


BREATH METHYLATED ALKANE CONTOUR
SYNTHESIS
METHYLATION SITE
8
6
4
2
ALVEOLAR GRADIENT
(Cbreath-Cair)
CARBON SKELETON LENGTH
20
CLEARANCE
Menssana Research, Inc



WHAT THE RESULTS MEAN

- VOCs are present in breath *<u>and</u>* room air
  → essential to measure *<u>both!</u>*
- *<u>Everyone</u>* has VOC markers of oxidative stress in their breath
- BMAC: displays >100 oxidative stress markers

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BREATH TESTING: THE FOUR QUESTIONS

HOW do we analyze breath?

WHAT do the results mean?

WHY do it?

WHERE is it leading?

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BREATH TESTS

Disease markers for the 21st century:

- *Accurate*
- *Non-invasive*
- *Cost-effective*
- *Safe*

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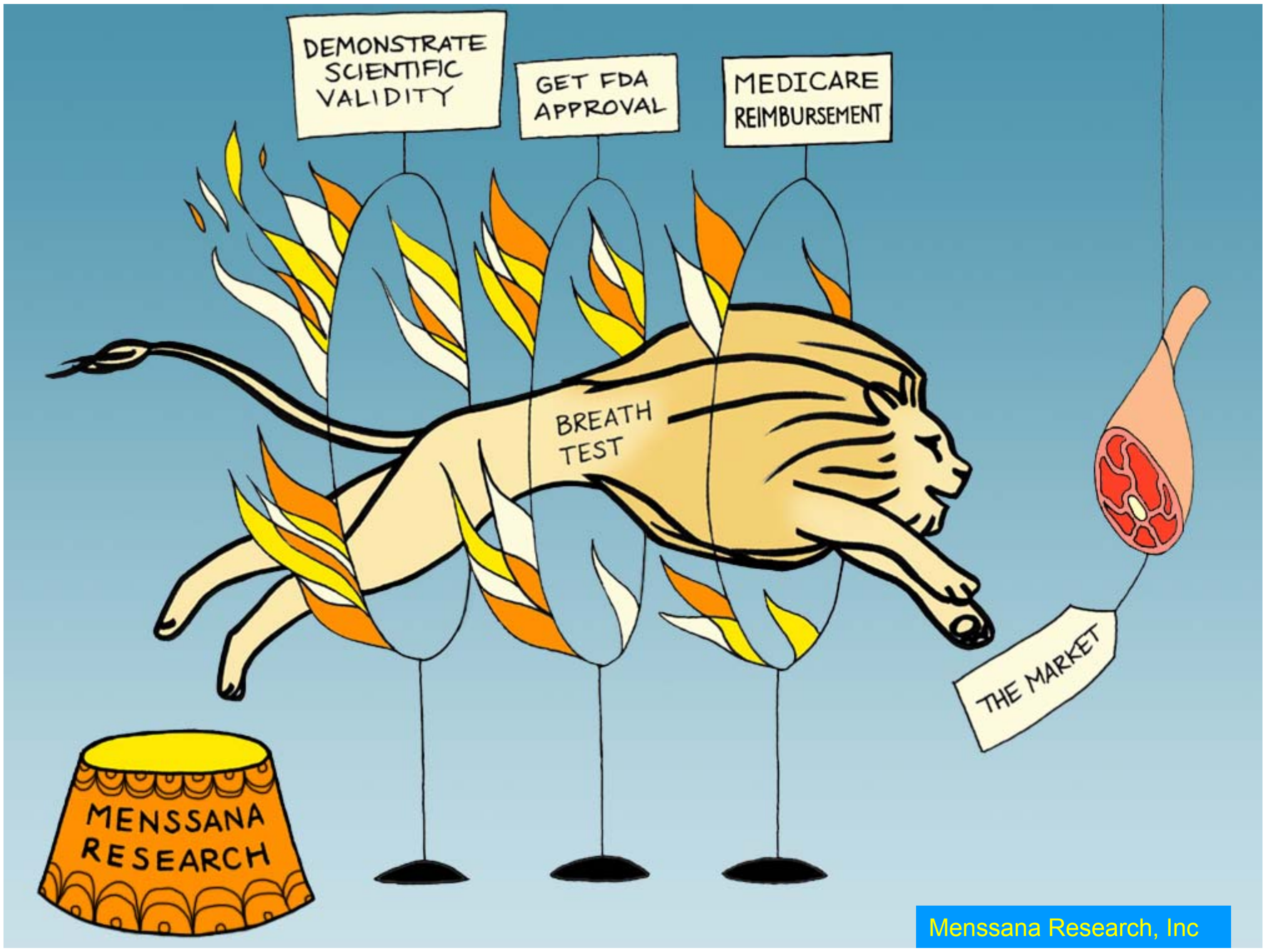
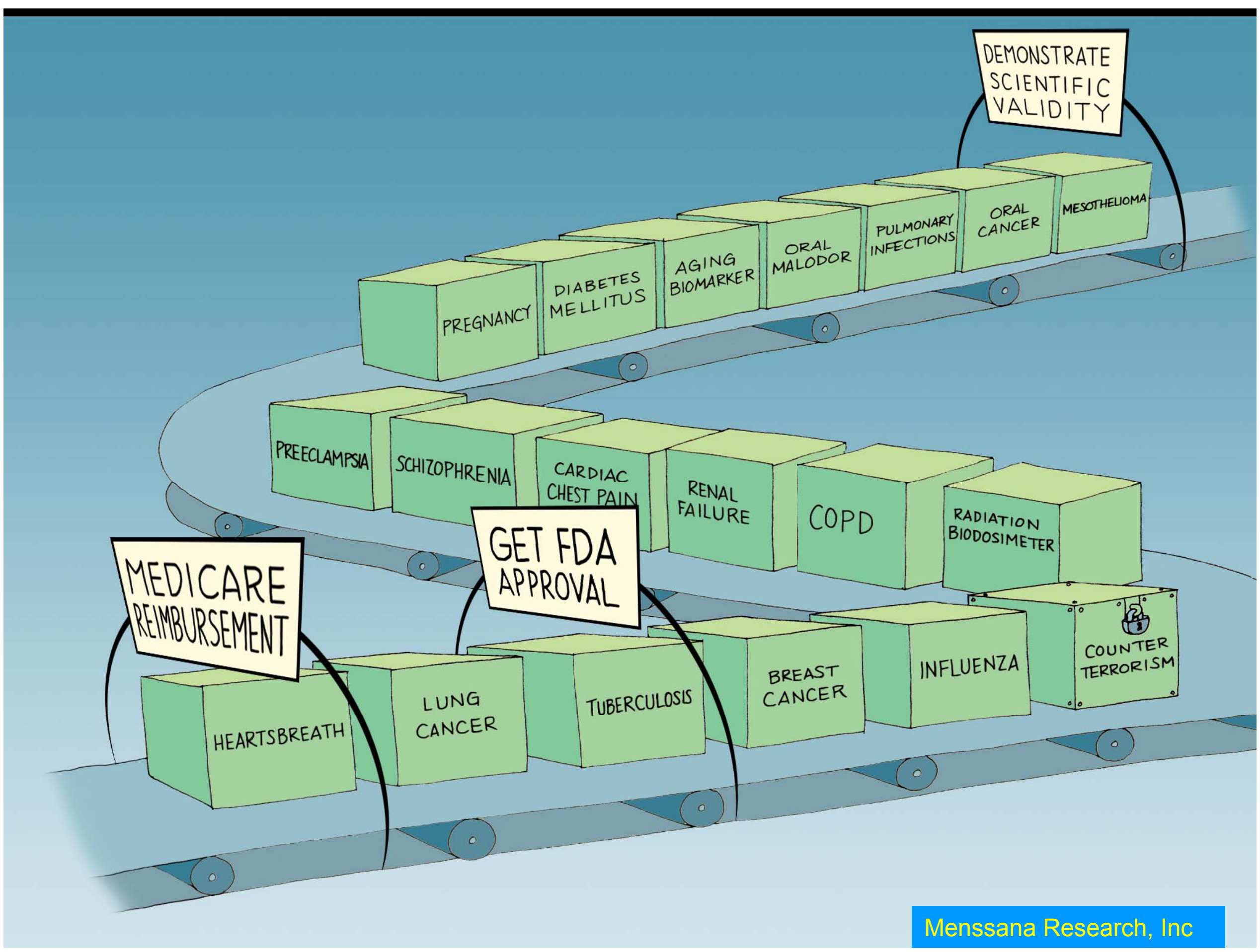

DEMONSTRATE SCIENTIFIC VALIDITY
GET FDA APPROVAL
MEDICARE REIMBURSEMENT
BREATH TEST
THE MARKET
MENSSANA RESEARCH
Menssana Research, Inc


DEMONSTRATE SCIENTIFIC VALIDITY
MESOTHELIOMA
ORAL CANCER
PULMONARY INFECTIONS
ORAL MALODOR
AGING BIOMARKER
DIABETES MELLITUS
PREGNANCY
PREECLAMPSIA
SCHIZOPHRENIA
CARDIAC CHEST PAIN
RENAL FAILURE
COPD
RADIATION BIODOSIMETER
GET FDA APPROVAL
MEDICARE REIMBURSEMENT
HEARTSBREATH
LUNG CANCER
TUBERCULOSIS
BREAST CANCER
INFLUENZA
COUNTER TERRORISM
Menssana Research, Inc

THE HEARTSBREATH TEST FOR HEART TRANSPLANT REJECTION

Menssana Research, Inc

The problem

- ~2,500 heart transplants a year – most in USA
- High risk of rejection in first year
- Patients monitored with ~20 heart biopsies

  → *Grade 0,1 or 2 versus grade 3*

  → *observe versus treat*
- Painful, invasive, poor accuracy
- *Expensive!* ~ $3,500 (Medicare → Aetna etc)

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Flaming hoop #1: Establish scientific validity

- NIH/NHLBI Phase I and Phase II SBIR awards
- Heart Allograft Rejection: Detection with Breath Alkanes in Low Levels (the HARDBALL study)
  - Seven academic medical centers
  - >1,100 patient studies

→ Heartsbreath test: sensitive and specific for Grade 3 rejection

J Heart Lung Transp 2004: 23: 701-8

Am J Cardiol 2004; 94:1593-1594.

Menssana Research, Inc

Flaming hoop #2: Get FDA approval

FDA U.S. Food and Drug Administration — Department of Health and Human Services

CENTER FOR DEVICES AND RADIOLOGICAL HEALTH

FDA Home Page | CDRH Home Page | Search | CDRH A-Z Index | Contact CDRH

CDRH Consumer Information

Consumer Home | Product Index and Information | Choosing a Medical Device | How We Can Help | Resources | Problems with Medical Devices

New Humanitarian Device Approval

Heartsbreath - H030004

FDA approved this device under the Humanitarian Device Exemption (HDE) program. See the links below to the Summary of Safety and Probable Benefit (SSPB) and other sites for more complete information on this product, its indications for use, and the basis for FDA's approval.

Product Name: Heartsbreath
Manufacturer: Menssana Research, Inc.
Address: 1 Horizon Road, Suite 1415, Fort Lee, NJ 07024-6510
Approval Date: February 24, 2004
Approval Letter: http://www.fda.gov/cdrh/ode/H030004sum.html

Menssana Research, Inc

We want you to know™

Aetna

Flaming hoop #3: Get insurance to pay for it

…Aetna considers the HeartsbreathTest (Menssana Research, Inc., Fort Lee, NJ) medically necessary for use as an aid to diagnosis of grade 3 heart transplant rejection in persons who have received heart transplants within the preceding year.

Menssana Research, Inc

We want you to know™

Aetna

…Aetna considers the HeartsbreathTest (Menssana Research, Inc., Fort Lee, NJ) medically necessary for use as an aid to diagnosis of grade 3 heart transplant rejection in persons who have received heart transplants within the preceding year.

Menssana Research, Inc

HHS.gov

Improving the health, safety and well-being of America

CMS Centers for **Medicare** & **Medicaid** Services

NCA Tracking Sheet for Heartsbreath Test for Heart Transplant Rejection (CAG-00394N)

- *National Coverage Determination – in progress*

Menssana Research, Inc

BREATH TEST FOR LUNG CANCER

3 multicenter clinical studies

Lancet 1998

Chest 2003

Cancer Biomarkers 2007

Similar findings in all studies

- Breath test sensitive and specific for lung cancer
- TNM stage → NO effect on accuracy of breath test
- Potential application:
- Early detection Stage 1 lung cancer

→ improve survival?

CONCLUSIONS FROM THIRD CLINICAL STUDY

- Breath test *predicts* lung cancer
- Predicts Stage 1 *before* metastasis
- Sensitivity and specificity similar to chest CT
- Predictions *not* affected by smoking
- Cost effective, safe screening test

→ early detection?
→ save lives?

Menssana Research, Inc

Tuberculosis (■■■■) ■, ■■■–■■■

ELSEVIER

Tuberculosis

http://intl.elsevierhealth.com/journals/tube

Volatile biomarkers of pulmonary tuberculosis in the breath

Michael Phillips[a,b,*], Renee N. Cataneo[a], Rany Condos[c], Gerry Ring Erickson[d], Joel Greenberg[a,*], Vincent La Bombardi[e], Muhammad I. Munawar[a], Olaf Tietje[f]

[a]*Menssana Research Inc., Fort Lee, NJ 07024, USA*
[b]*Department of Medicine, New York Medical College, Valhalla, NY, USA*
[c]*Division of Pulmonary and Critical Care Medicine, Bellevue Chest Service, NYU School of Medicine, New York, NY, USA*
[d]*Infometrix, Inc, Woodinville, WA, USA*
[e]*Saint Vincent's Medical Center, New York, NY, USA*
[f]*SystAim GmbH, Pfingstweidstr. 31a, CH 8005 Zürich, Switzerland*

Received 14 December 2005; received in revised form 8 March 2006; accepted 10 March 2006

Menssana Research, Inc

How can a breath test identify patients with active pulmonary TB?

Menssana Research, Inc

How can a breath test identify patients with active pulmonary TB?

…Because VOC biomarkers in breath are the same or similar to VOC metabolites of Mycobacteria in vitro!

Menssana Research, Inc

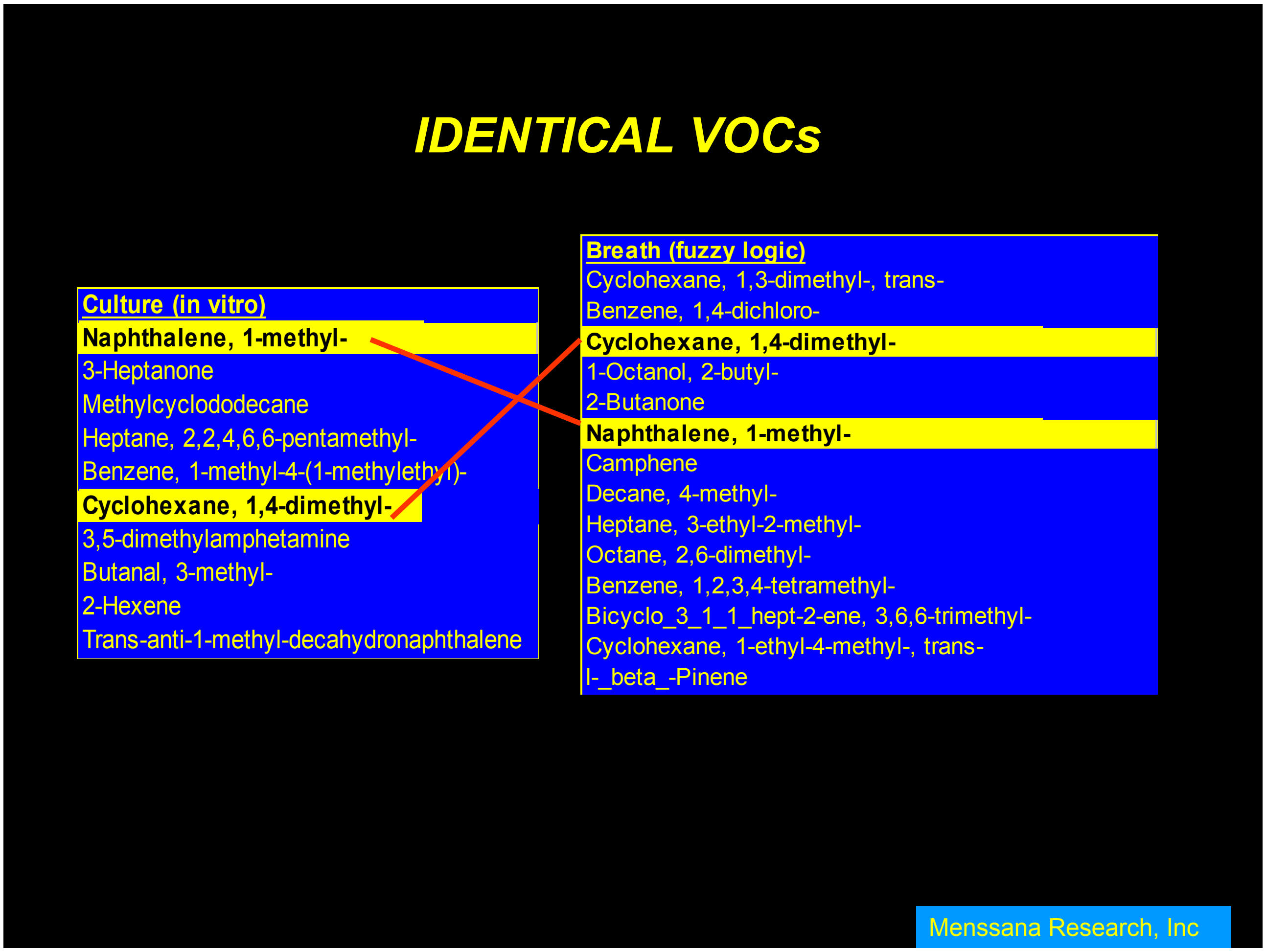
VOC biomarkers of Mycobacteria

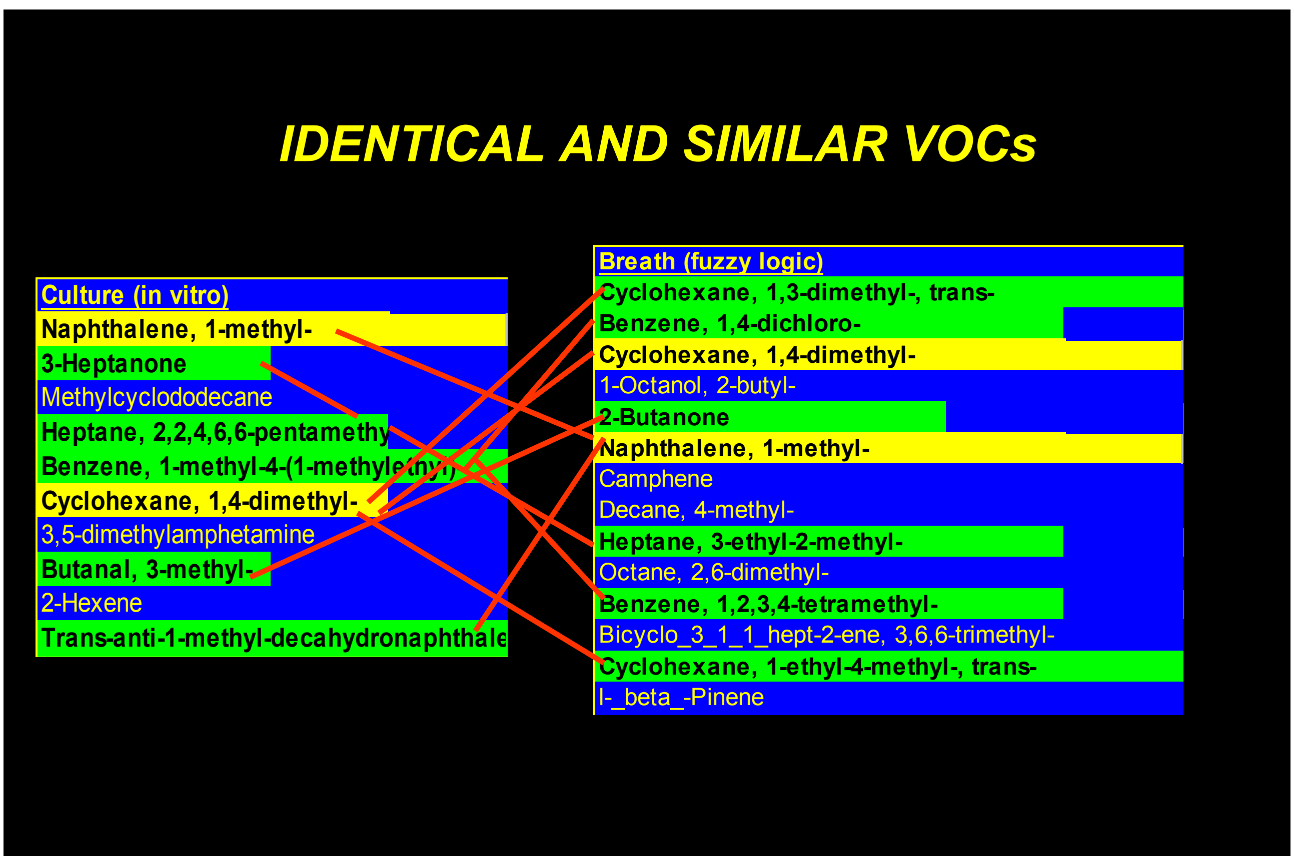
Culture (in vitro)
Naphthalene, 1-methyl-
3-Heptanone
Methylcyclododecane
Heptane, 2,2,4,6,6-pentamethyl-
Benzene, 1-methyl-4-(1-methylethyl)-
Cyclohexane, 1,4-dimethyl-
3,5-dimethylamphetamine
Butanal, 3-methyl-
2-Hexene
Trans-anti-1-methyl-decahydronaphthalene

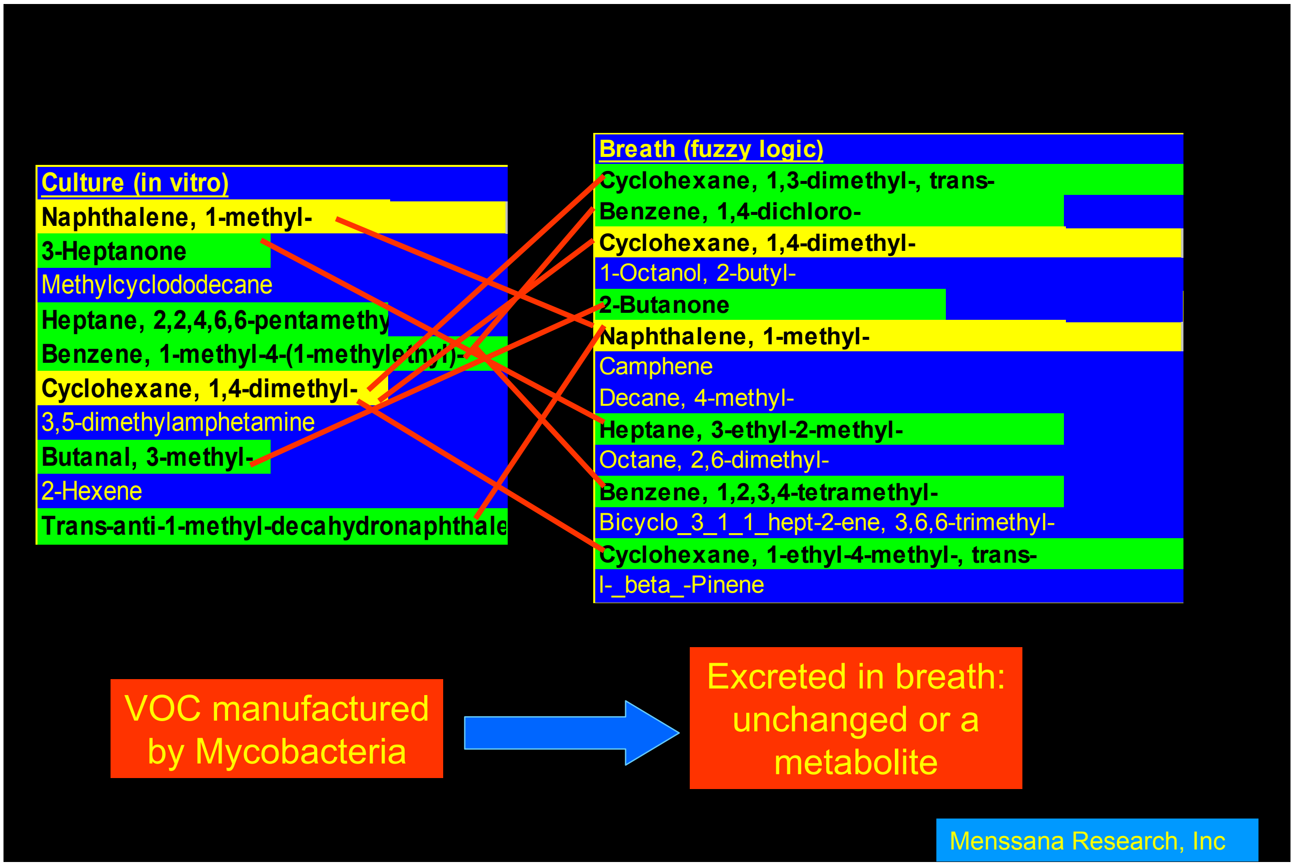
Menssana Research, Inc

Culture (in vitro)
Naphthalene, 1-methyl-
3-Heptanone
Methylcyclododecane
Heptane, 2,2,4,6,6-pentamethyl-
Benzene, 1-methyl-4-(1-methylethyl)-
Cyclohexane, 1,4-dimethyl-
3,5-dimethylamphetamine
Butanal, 3-methyl-
2-Hexene
Trans-anti-1-methyl-decahydronaphthalene

Breath (fuzzy logic)
Cyclohexane, 1,3-dimethyl-, trans-
Benzene, 1,4-dichloro-
Cyclohexane, 1,4-dimethyl-
1-Octanol, 2-butyl-
2-Butanone
Naphthalene, 1-methyl-
Camphene
Decane, 4-methyl-
Heptane, 3-ethyl-2-methyl-
Octane, 2,6-dimethyl-
Benzene, 1,2,3,4-tetramethyl-
Bicyclo_3_1_1_hept-2-ene, 3,6,6-trimethyl-
Cyclohexane, 1-ethyl-4-methyl-, trans-
l-_beta_-Pinene


IDENTICAL VOCs
Culture (in vitro)
Naphthalene, 1-methyl-
3-Heptanone
Methylcyclododecane
Heptane, 2,2,4,6,6-pentamethyl-
Benzene, 1-methyl-4-(1-methylethyl)-
Cyclohexane, 1,4-dimethyl-
3,5-dimethylamphetamine
Butanal, 3-methyl-
2-Hexene
Trans-anti-1-methyl-decahydronaphthalene
Breath (fuzzy logic)
Cyclohexane, 1,3-dimethyl-, trans-
Benzene, 1,4-dichloro-
Cyclohexane, 1,4-dimethyl-
1-Octanol, 2-butyl-
2-Butanone
Naphthalene, 1-methyl-
Camphene
Decane, 4-methyl-
Heptane, 3-ethyl-2-methyl-
Octane, 2,6-dimethyl-
Benzene, 1,2,3,4-tetramethyl-
Bicyclo_3_1_1_hept-2-ene, 3,6,6-trimethyl-
Cyclohexane, 1-ethyl-4-methyl-, trans-
l-_beta_-Pinene
Menssana Research, Inc


IDENTICAL AND SIMILAR VOCs
Culture (in vitro)
Naphthalene, 1-methyl-
3-Heptanone
Methylcyclododecane
Heptane, 2,2,4,6,6-pentamethy
Benzene, 1-methyl-4-(1-methylethyl)-
Cyclohexane, 1,4-dimethyl-
3,5-dimethylamphetamine
Butanal, 3-methyl-
2-Hexene
Trans-anti-1-methyl-decahydronaphthale
Breath (fuzzy logic)
Cyclohexane, 1,3-dimethyl-, trans-
Benzene, 1,4-dichloro-
Cyclohexane, 1,4-dimethyl-
1-Octanol, 2-butyl-
2-Butanone
Naphthalene, 1-methyl-
Camphene
Decane, 4-methyl-
Heptane, 3-ethyl-2-methyl-
Octane, 2,6-dimethyl-
Benzene, 1,2,3,4-tetramethyl-
Bicyclo_3_1_1_hept-2-ene, 3,6,6-trimethyl-
Cyclohexane, 1-ethyl-4-methyl-, trans-
l-_beta_-Pinene



BREATH TESTING: THE FOUR QUESTIONS

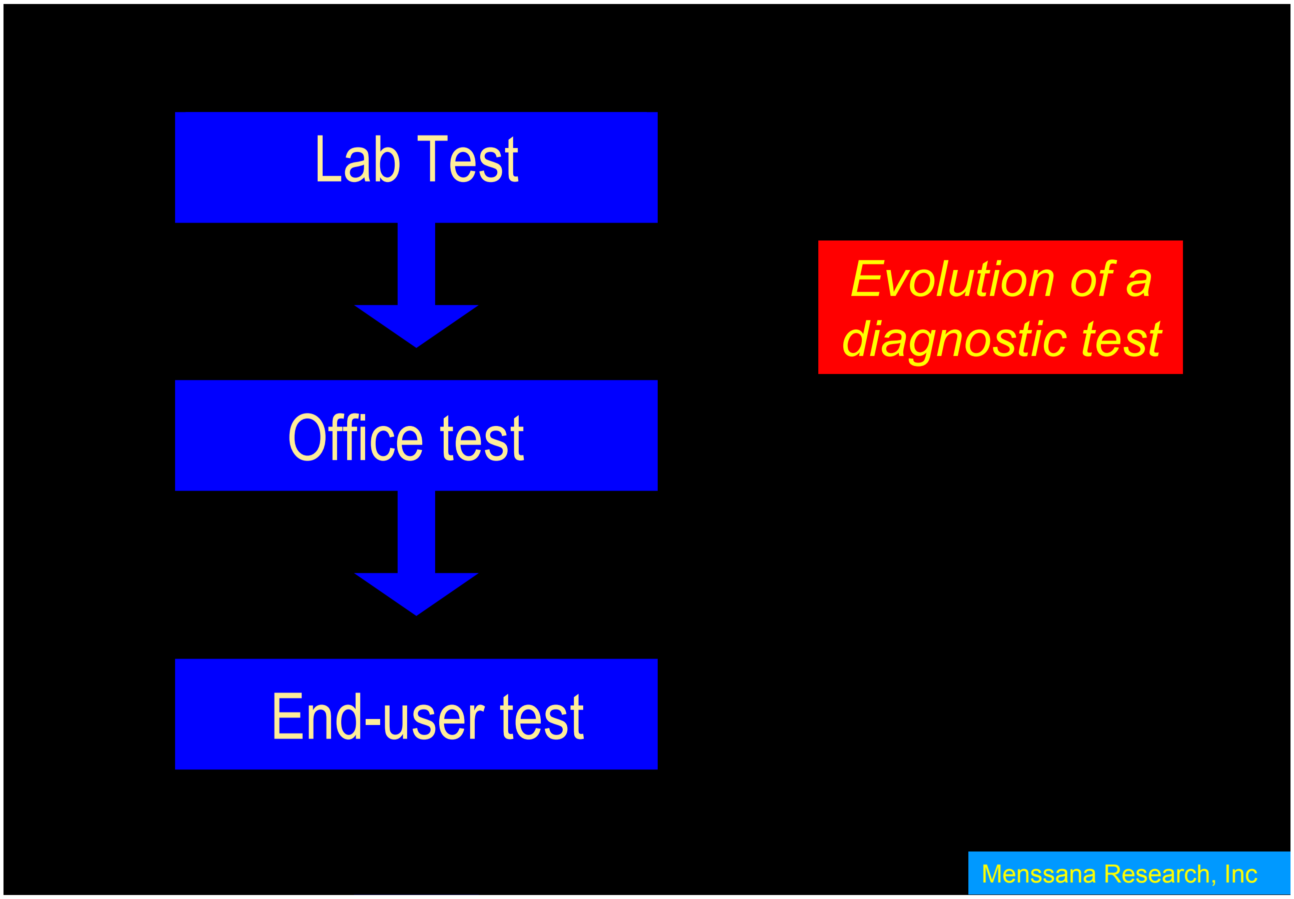
HOW do we analyze breath?

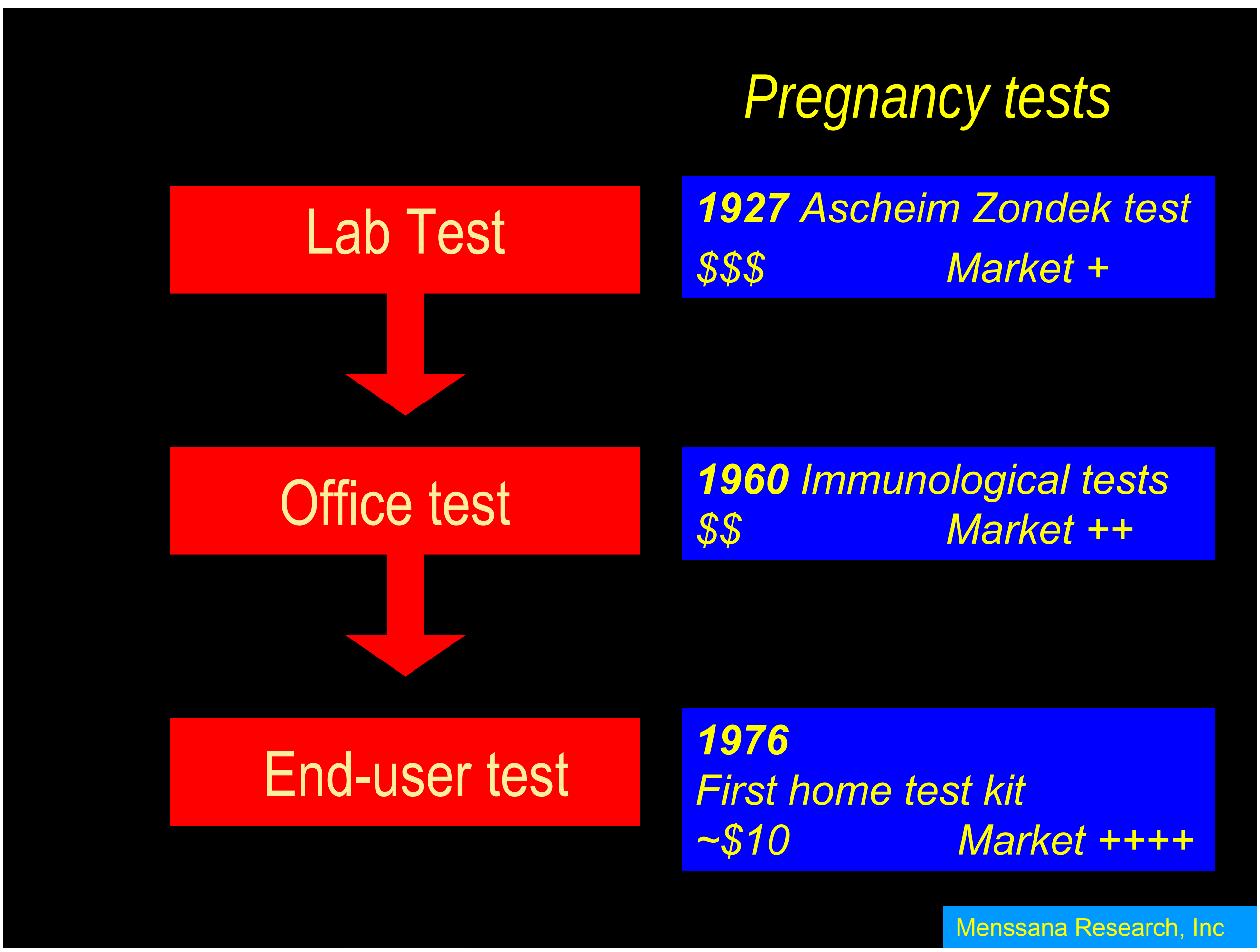
WHAT do the results mean?

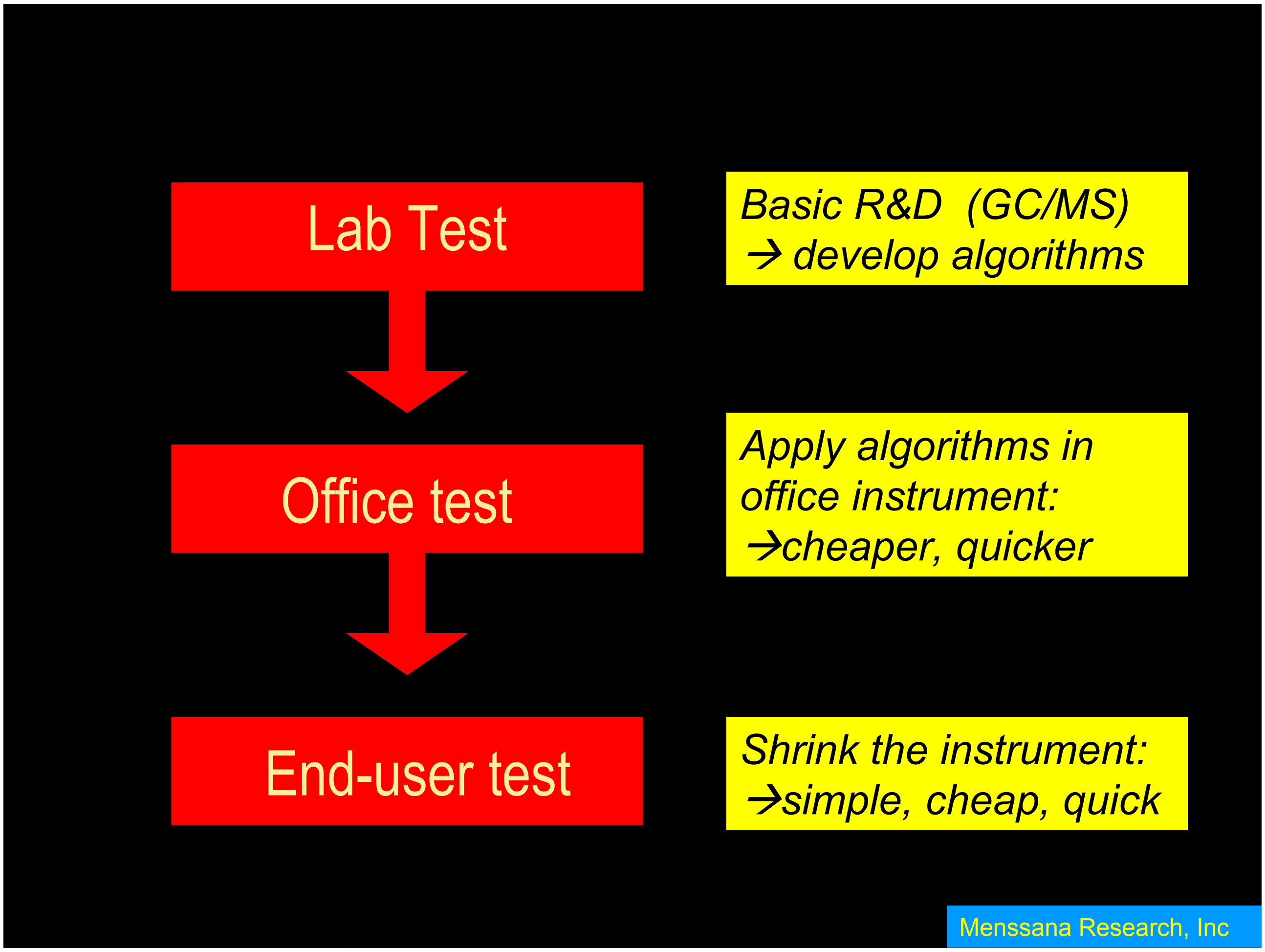
WHY do it?

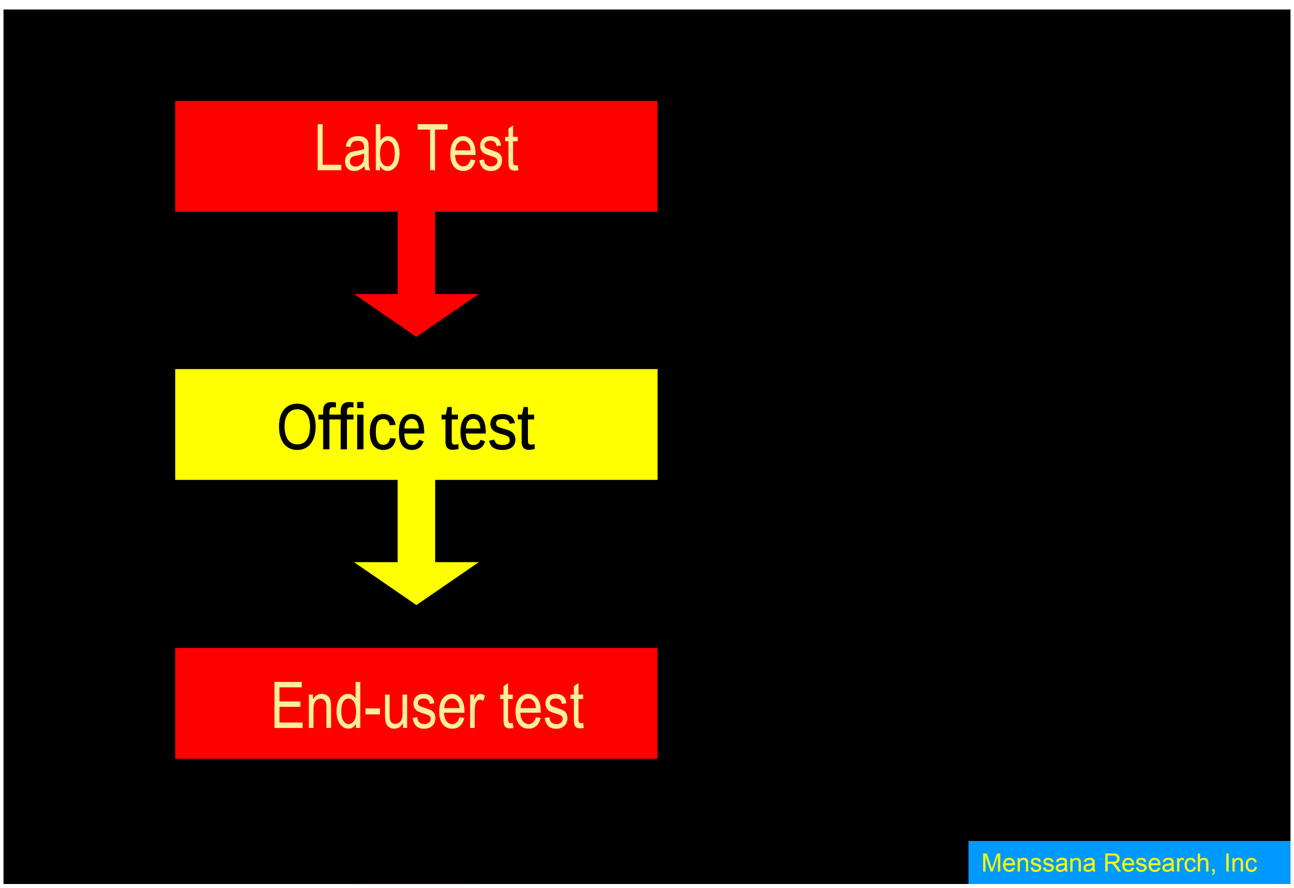
WHERE is it leading?

Menssana Research, Inc

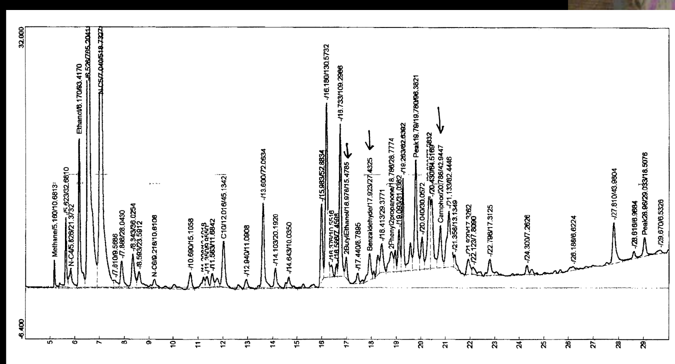

Lab Test
Office test
End-user test
Evolution of a diagnostic test
Menssana Research, Inc


Pregnancy tests
Lab Test
Office test
End-user test
1927 Ascheim Zondek test
$$$ Market +
1960 Immunological tests
$$ Market ++
1976
First home test kit
~$10 Market ++++
Menssana Research, Inc

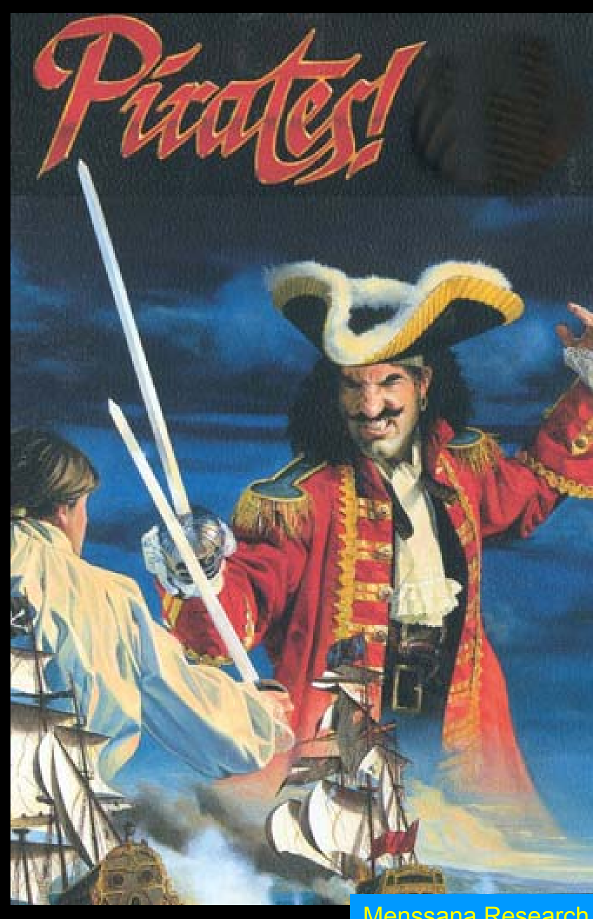

Lab Test
Office test
End-user test
Basic R&D (GC/MS)
→ develop algorithms
Apply algorithms in
office instrument:
→cheaper, quicker
Shrink the instrument:
→simple, cheap, quick
Menssana Research, Inc


Lab Test
Office test
End-user test
Menssana Research, Inc

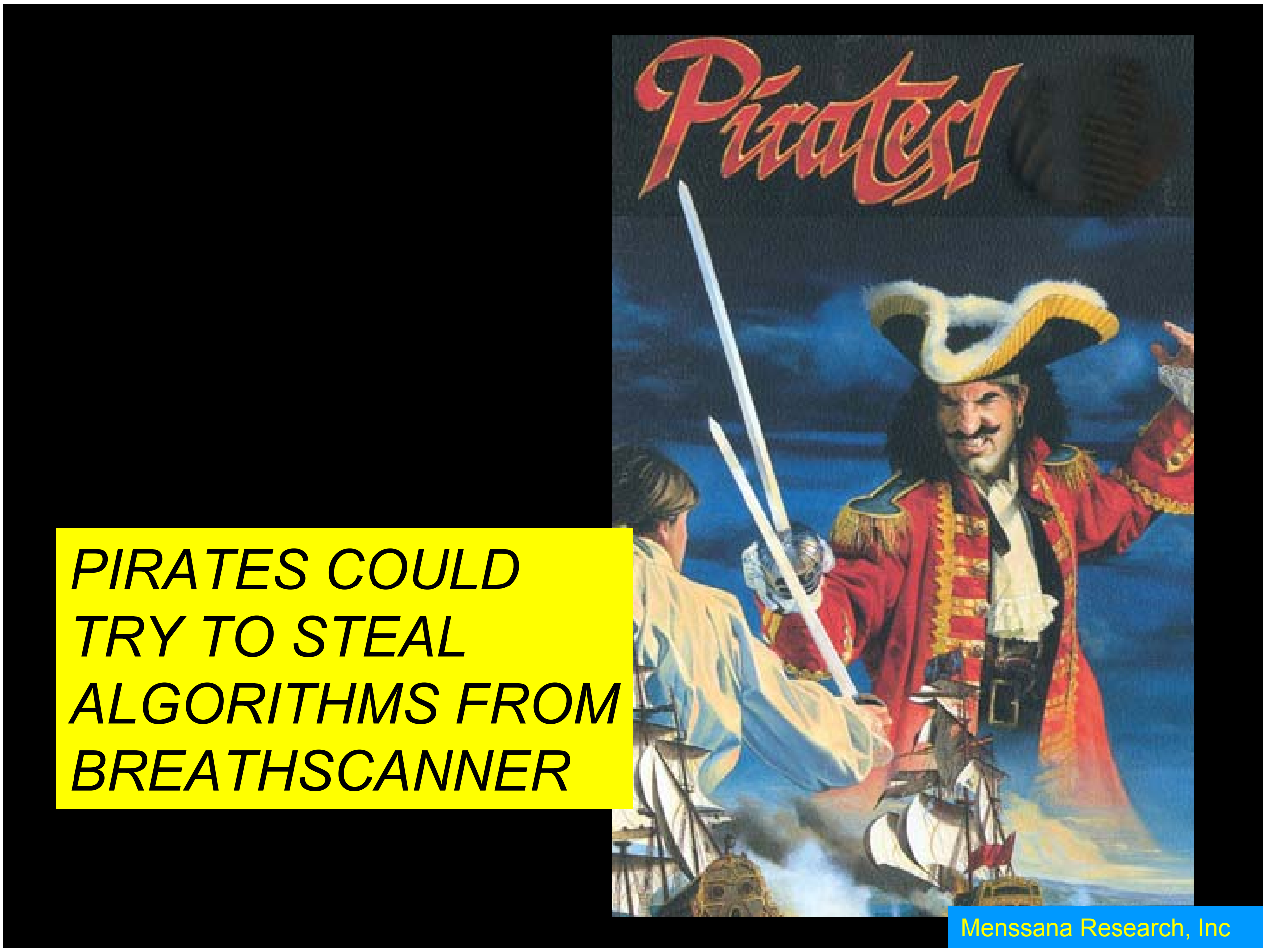
Breathscanner 2.5
Point-of-care breath test
Runs on water and electricity
Results in minutes

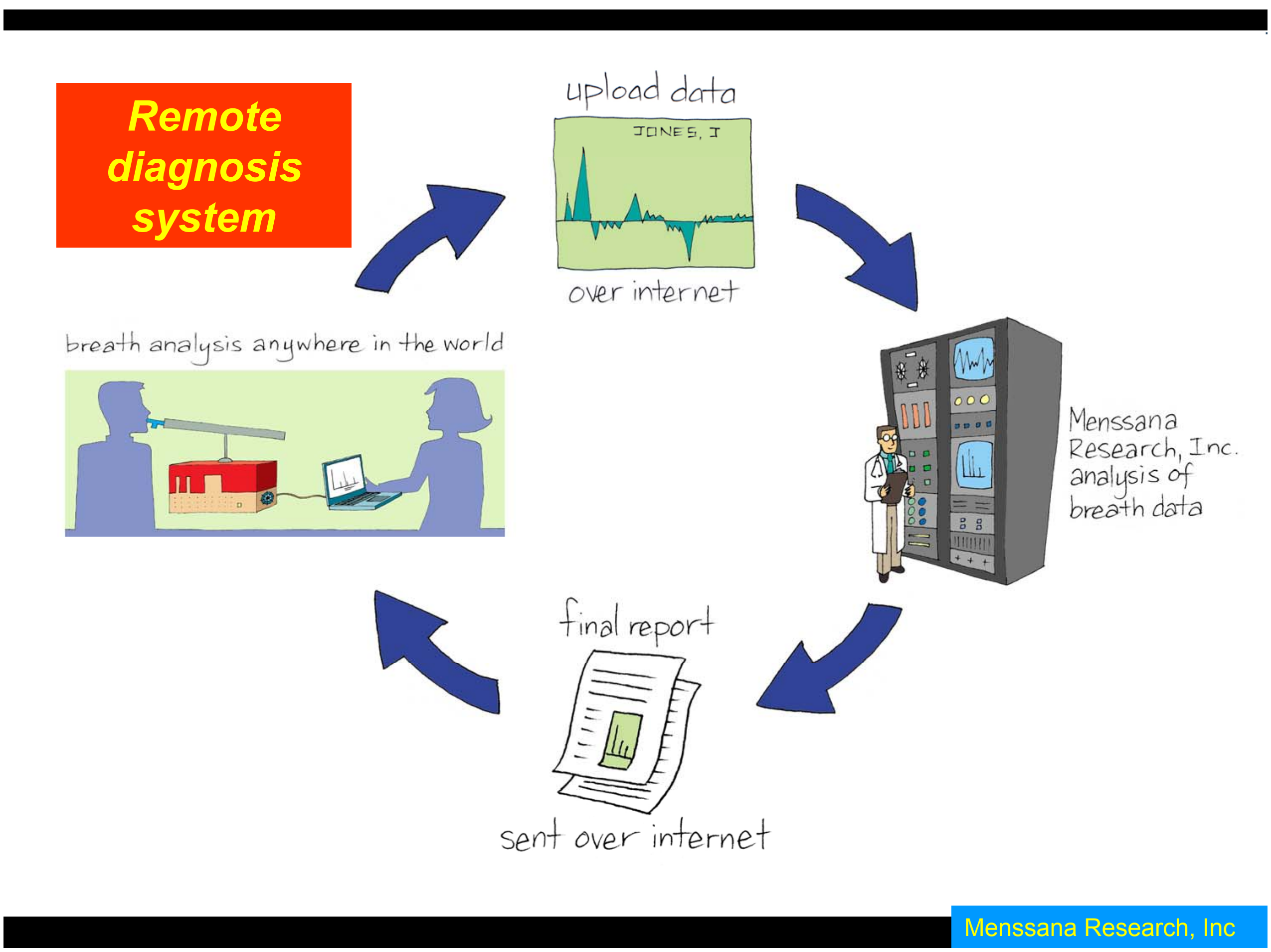


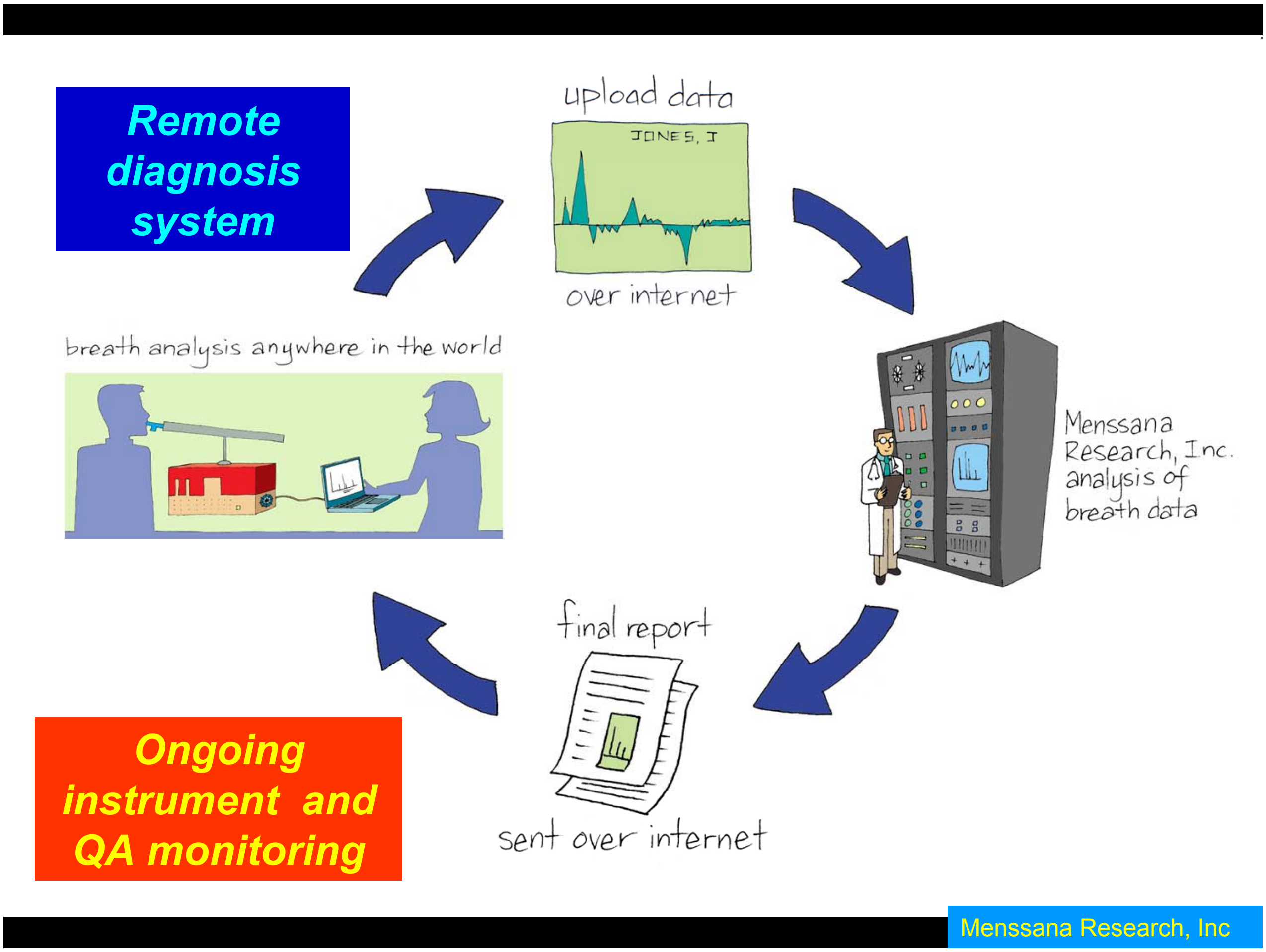
One more problem….



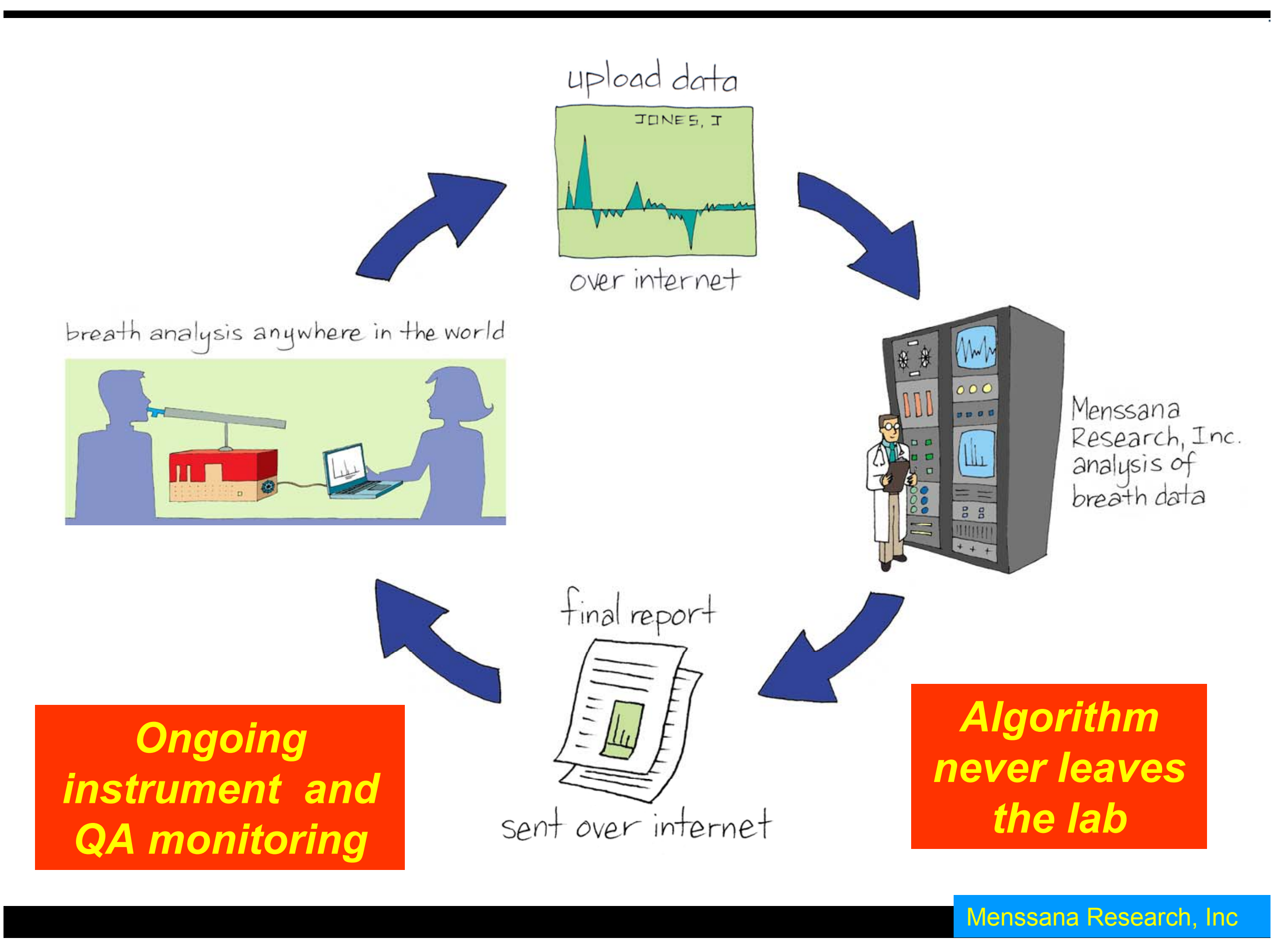
Menssana Research, Inc


Pirates!
PIRATES COULD TRY TO STEAL ALGORITHMS FROM BREATHSCANNER
Menssana Research, Inc

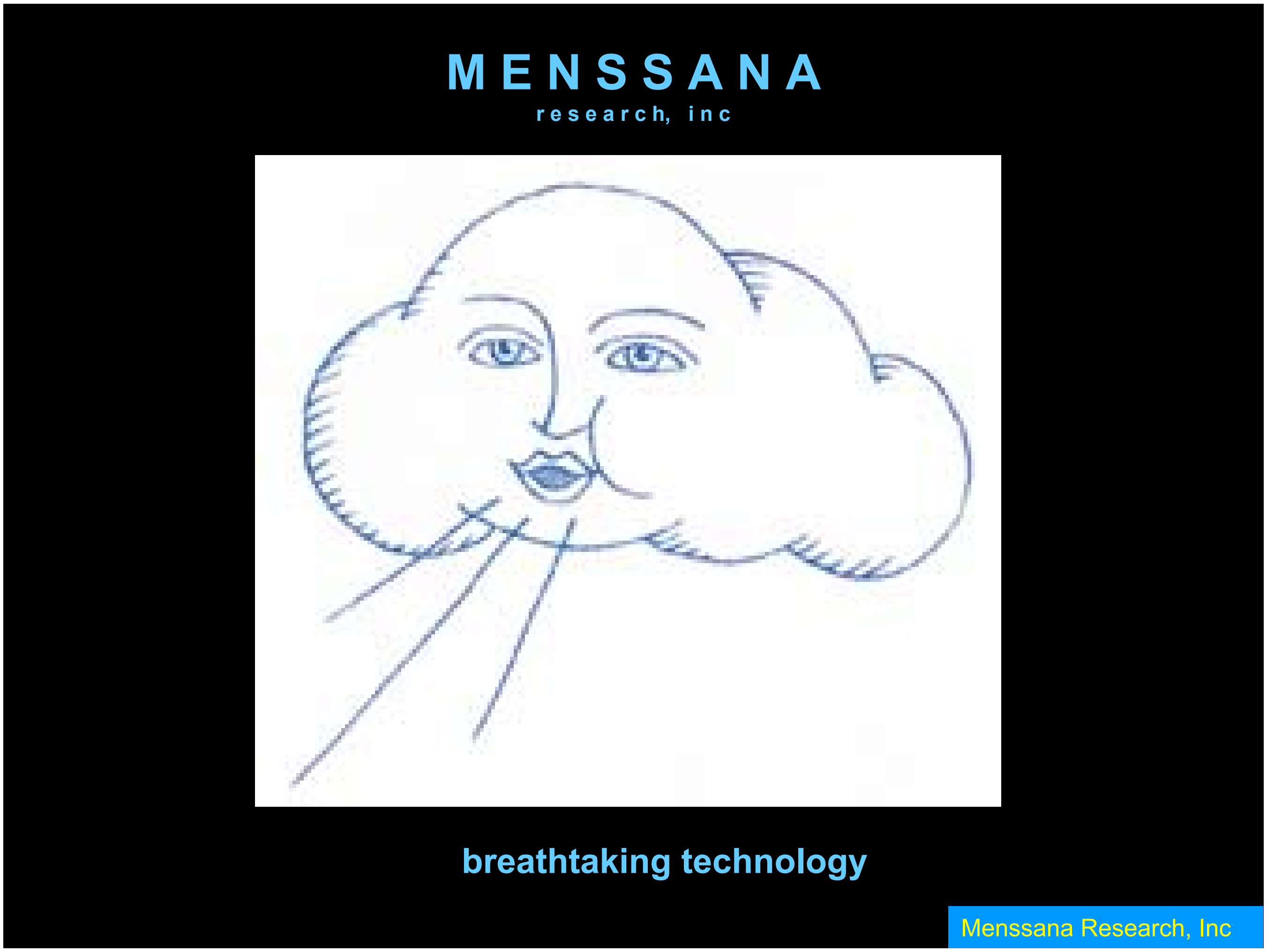

Remote diagnosis system
upload data
JONES, J
over internet
breath analysis anywhere in the world
Menssana Research, Inc. analysis of breath data
final report
sent over internet
Menssana Research, Inc



Remote diagnosis system
upload data
JONES, J
over internet
breath analysis anywhere in the world
Menssana Research, Inc. analysis of breath data
final report
sent over internet
Ongoing instrument and QA monitoring
Menssana Research, Inc



upload data
JONES, J
over internet
breath analysis anywhere in the world
Menssana Research, Inc. analysis of breath data
final report
sent over internet
Ongoing instrument and QA monitoring
Algorithm never leaves the lab
Menssana Research, Inc


MENSSANA
research, inc
breathtaking technology
Menssana Research, Inc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WORKSHOP

Nanotechnology-Based Electrochemical Sensors for Biomonitoring Chemical Exposures

NIOSH DREAM Methods Workshop
Session 6- Surface Sampling/Biomonitoring

November 13-14th 2008

Charles Timchalk, PhD DABT
Biological Monitoring & Modeling
Pacific Northwest National Laboratory
charles.timchalk@pnl.gov

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Focus of Presentation

- Need for direct reading exposure assessment methods
- Strategy for development & validation
- Example organophosphorus insecticides
  - Biomarker targets
  - Sensor development strategy
- Modeling strategy for interpretation of biomonitoring results
- Future directions & conclusions

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Occupational
Terrorism
Non- or Minimally
Invasive
Biological Monitoring
Children
Natural Disasters
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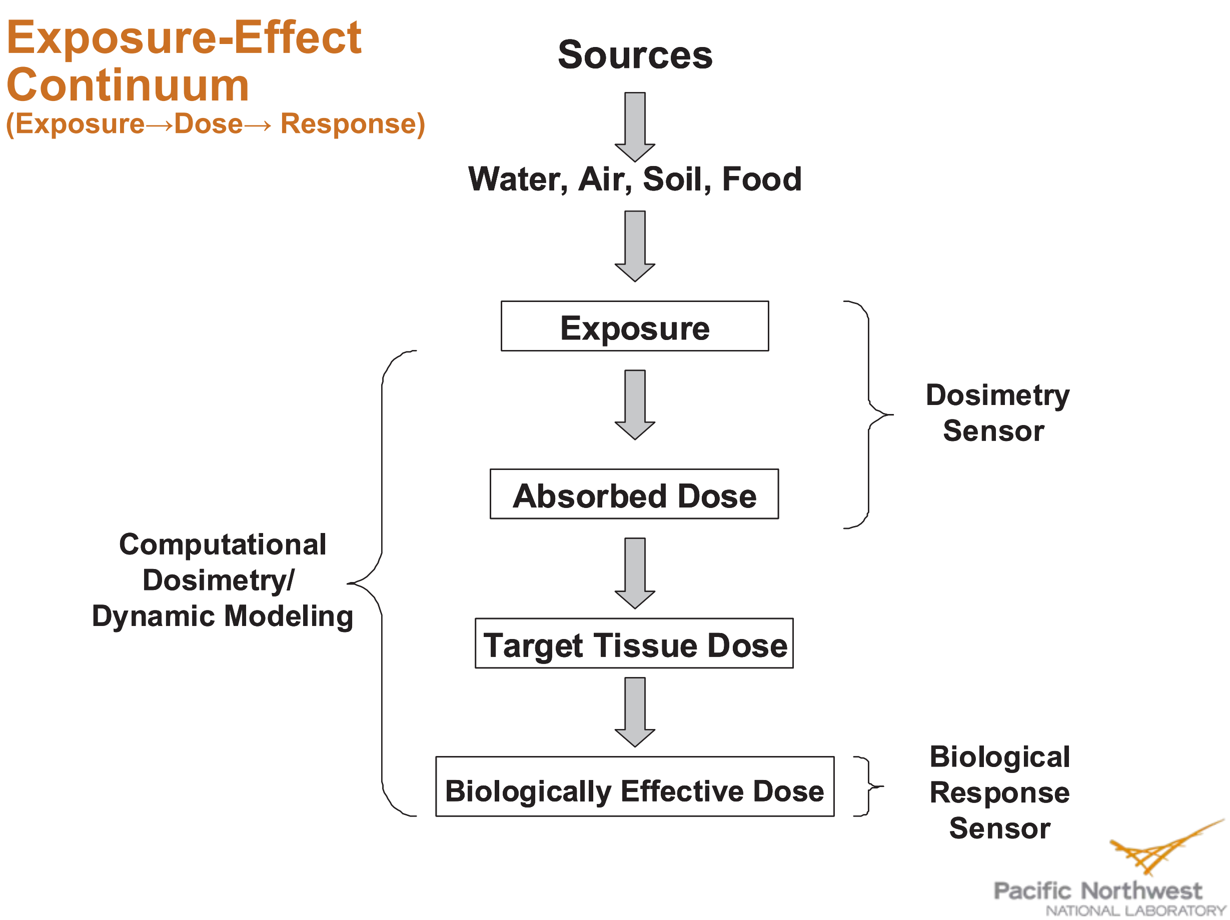
Exposure-Effect
Continuum
(Exposure→Dose→ Response)
Sources
Water, Air, Soil, Food
Exposure
Absorbed Dose
Target Tissue Dose
Biologically Effective Dose
Dosimetry
Sensor
Computational
Dosimetry/
Dynamic Modeling
Biological
Response
Sensor
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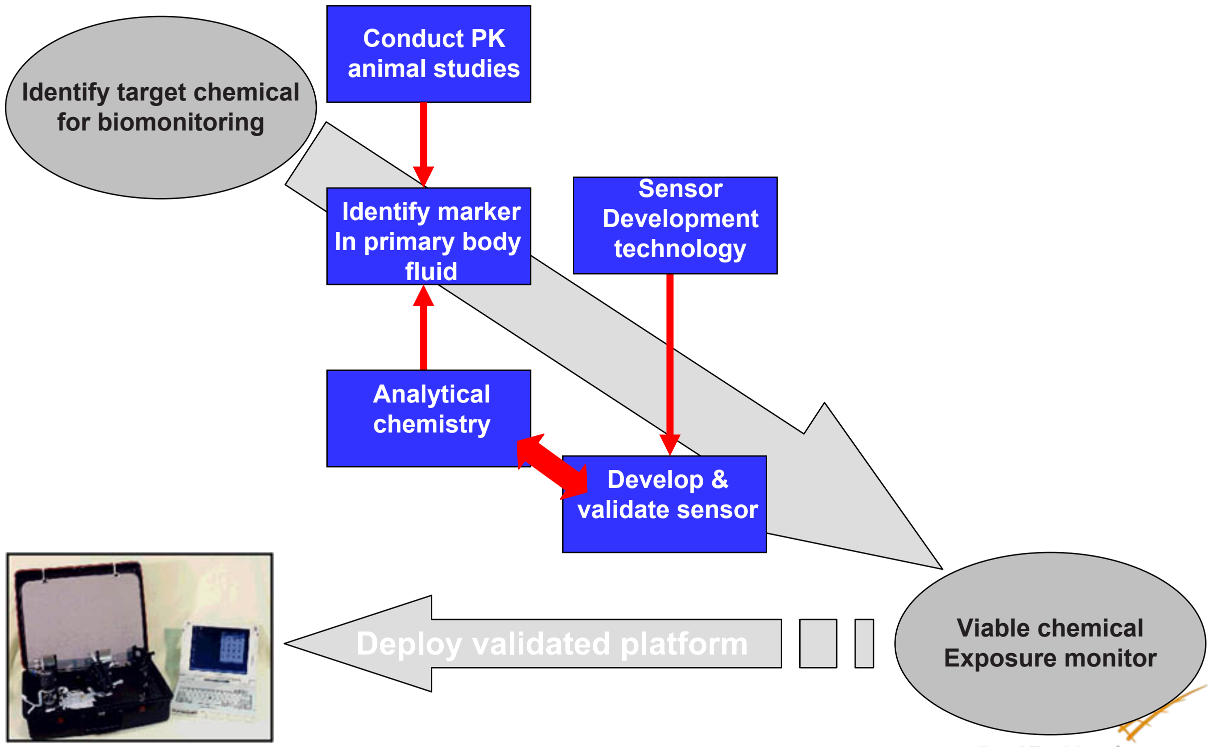
Sensor Development Strategy



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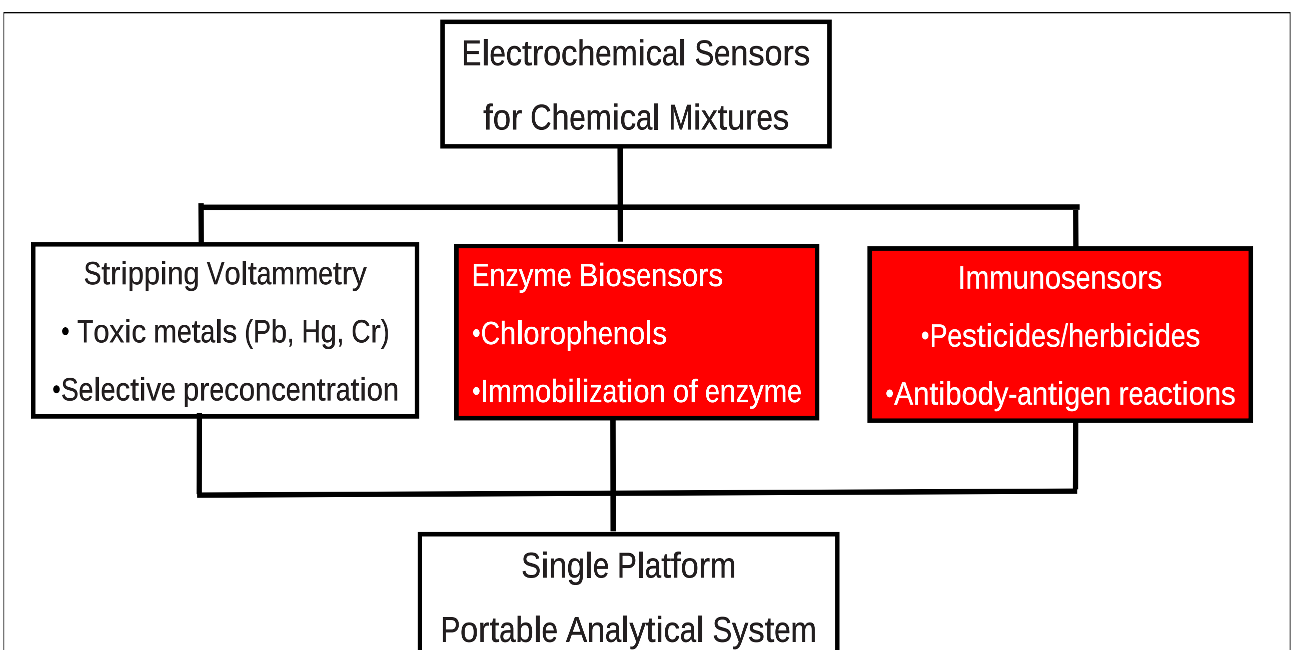
Sensor Development (Electrochemical)



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Organophosphorus Agents (Pesticides & Chemical Warfare agents)

- Organophosphorus insecticide toxicity is associated with the inhibition of acetylcholinesterase (AChE) producing excess cholinergic stimulation.
  - Acute cholinergic crisis –SLUD/death
  - Chronic effects-delayed neuropathy
  - Children's sensitivity- neurodevelopmental effects
- Focus on organophosphorus insecticide biomonitoring
  - Cholinesterase inhibition (blood)
  - Metabolite measurement (urine)
  - Protein biomarkers (phosphorylated AChE)

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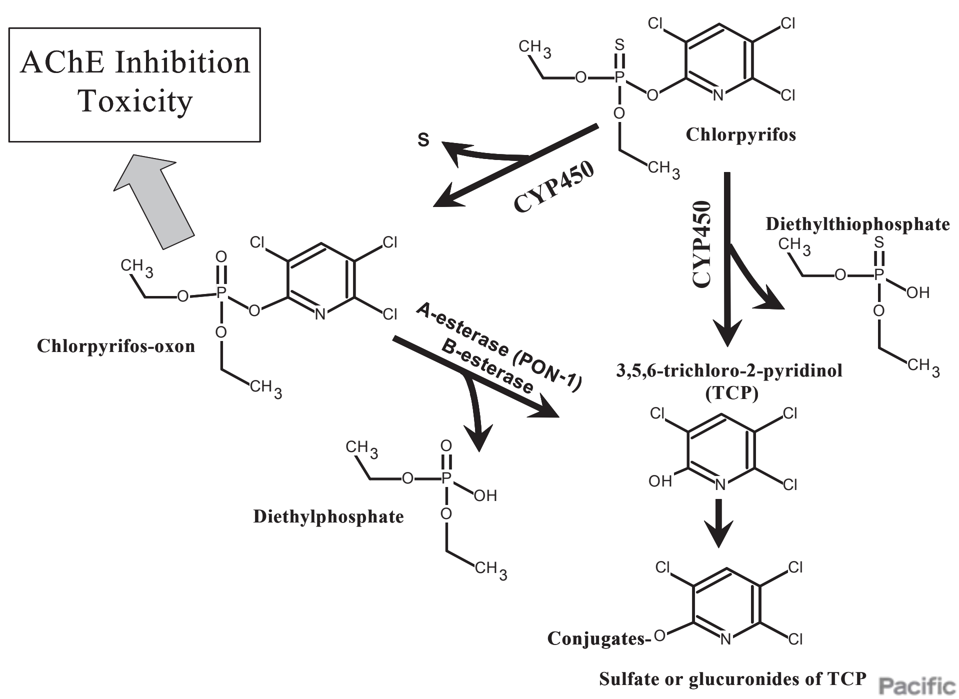
Metabolism of Chlorpyrifos (Dursban®)



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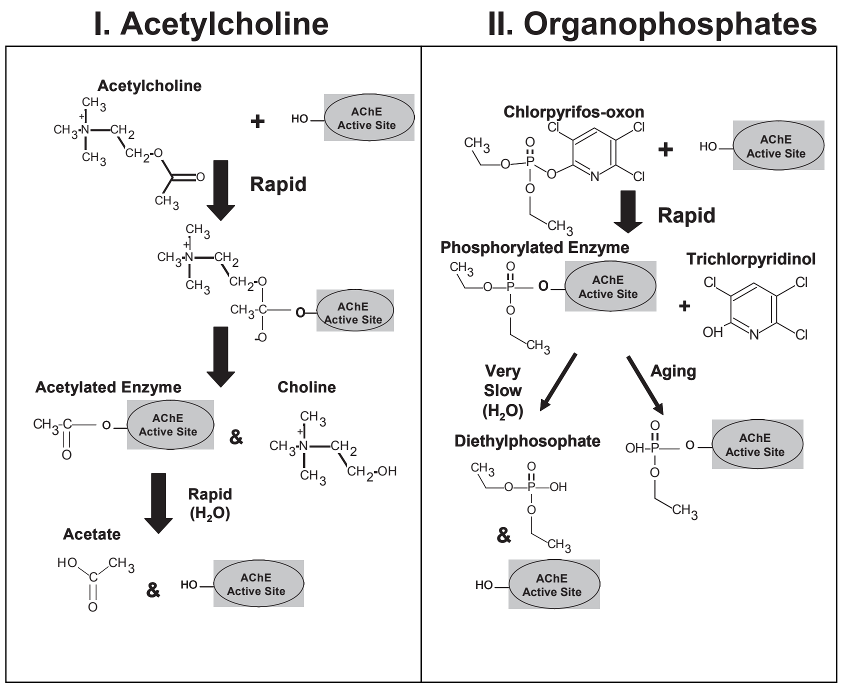
OP Pesticide Mode of Action: Cholinesterase (ChE) Inhibition



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Examples of: Organophosphorus Insecticide Sensor Platforms

Sequential/injection immunoassay	Carbon nanotube-sensor for enzyme activity	Nano-particle immunosensor for phosphorylated AChE
Quantitation of pesticide metabolite (breakdown product)	Quantitation of cholinesterase activity	Quantitation of modified AChE
Liu *et al* **(2005)** *Electrochem. Comm.*, **7: 1463-1470.**	**Wang** *et al* **(2008)** *Environ. Sci Tech.*, **42: 2688-2693.**	**Liu** *et al* **(2008)** *Chem. Eur. J..*, **(in press).**

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Sequential Injection/Electrochemical Immunoassay: TCP

- SIA system utilizes a thin layer electrochemical cell and permanent magnet to fix TCP antibody coated beads in reaction zone.
- Substrate solution + HRP-TCP →electroactive product.
- Monitored by square wave voltammetry.

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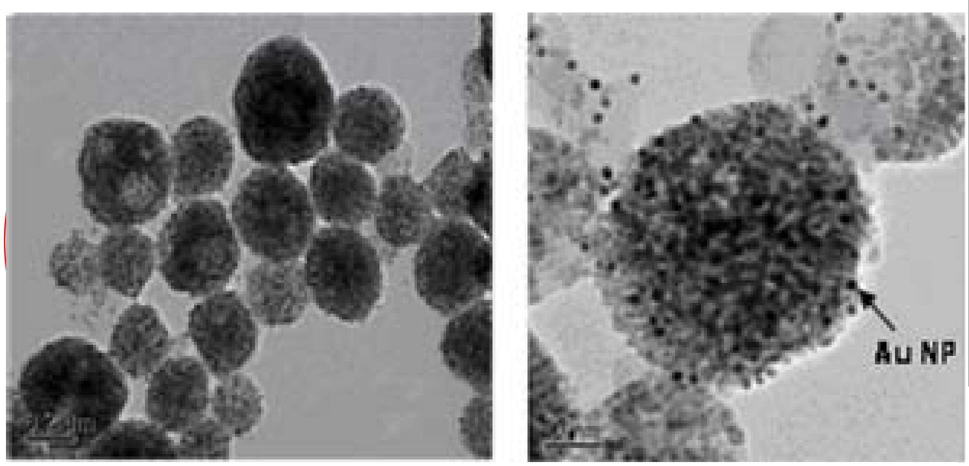
Sequential Injection/Electrochemical Immunoassay: TCP



Thin Layer Flow cell Electrochemical Detection

TEM- Magnetic Bead-gold nanoparticle assembly

Liu et al., 2005

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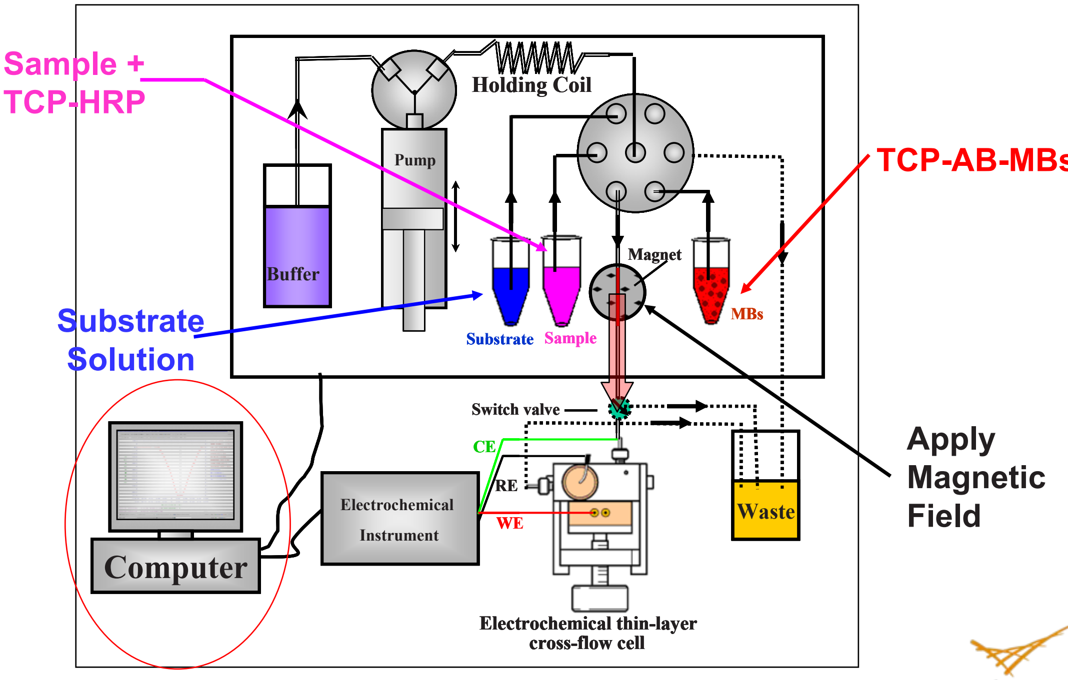
Sequential Injection/Electrochemical Immunoassay: TCP



Liu et al., 2005

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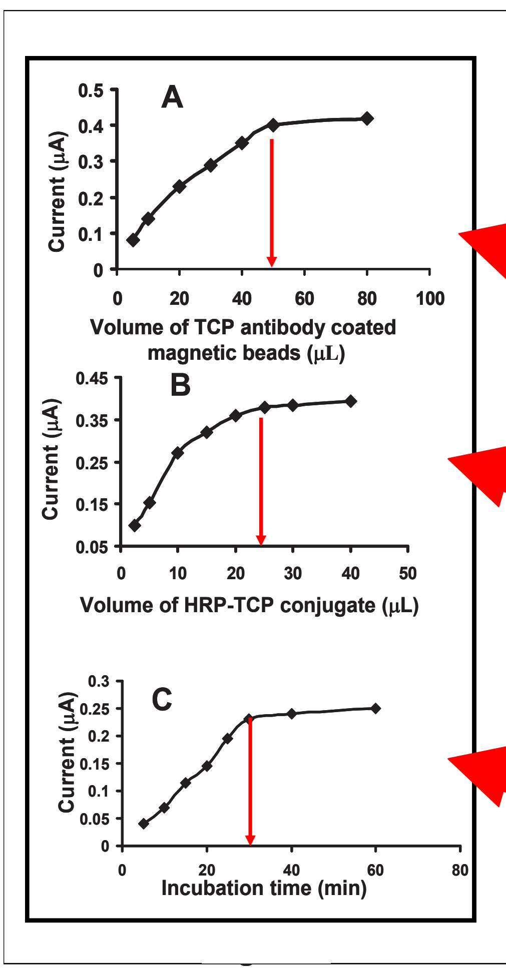

Optimization of Immunoassay Conditions

Impact of amount of MB on sensor response

Impact of HRP-TCP conjugate on sensor response

Impact of incubation time on sensor response

Liu et al., 2005

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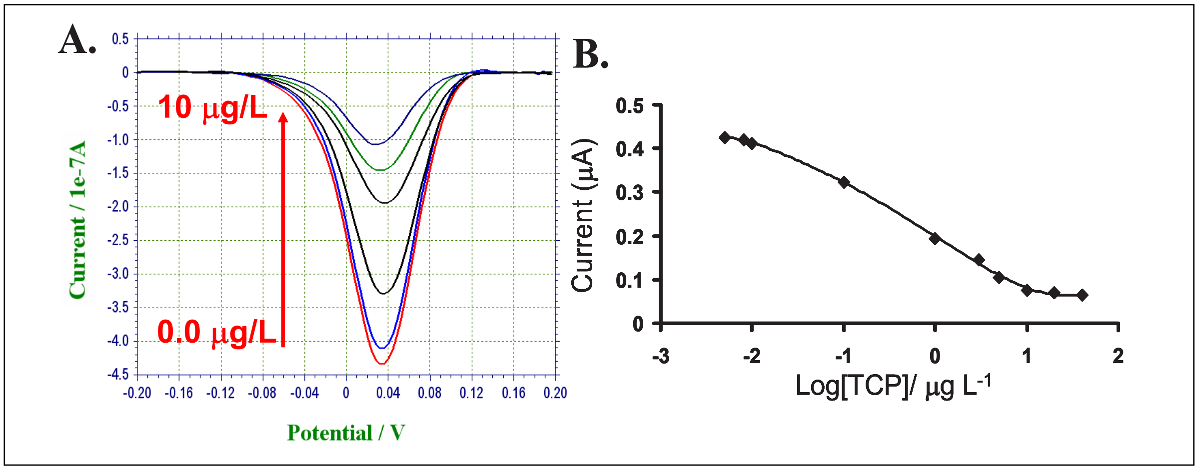
Analytical Performance

$$SWVsignal = \frac{[TCP - Ab - MBs]}{[TCP - HRP]} = \frac{1}{[TCP]}$$



Detection Limit – 6 ng/L (ppt) 50-fold lower that ELISA (250 ng/L)

Liu et al., 2005

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Summary: Sequential Injection/Electrochemical Immunoassay: TCP

- Parameters for SIA system optimized.
- Detection of TCP in low ppt range.
- Attractive approach for online immunoanalysis of aqueous systems without sample pretreatment.
- Ongoing *in vitro* studies will evaluate, refine and further optimize system for use with more complex biological matrices.

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Carbon nanotube (CNT), screen-printed electrode (SPE) for ChE enzyme activity

- Electrochemical sensor based on carbon nanotube (CNT)-modified screen-printed electrode (SPE) integrated into a flow cell.
- Based on the excellent electrocatalytic activity of the CNT, the sensor detects electroactive species at high sensitivity and low potentials.
- Electrochemical techniques combined with flow-injection systems offers a simple and inexpensive approach for rapid onsite biomonitoring of enzyme activity.
- A disposable SPE was employed:
  - CNT-modified working electrode
  - Ag/AgCl reference electrode
  - Carbon ring counter electrode

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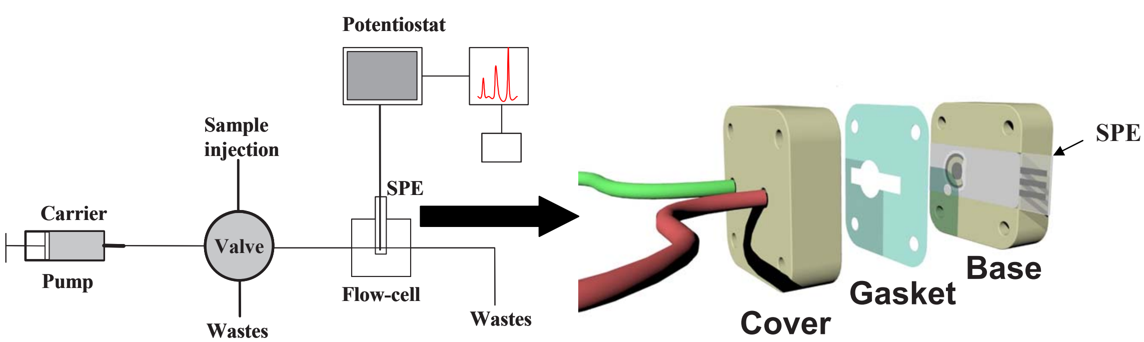
Flow-Injection Sensing System for ChE Enzyme Activity Measurement



$$\text{Acetylthiocholine} + H_20 \xrightarrow{\text{ChE}} \text{thiocholine (TCh)} + \text{acetic acid}$$

$$2\text{TCh (red)} \rightarrow \text{TCh (ox)} + 2H^+ + 2e^-$$

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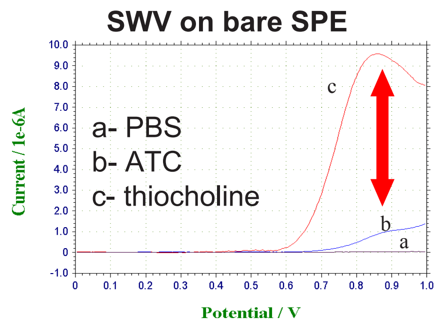
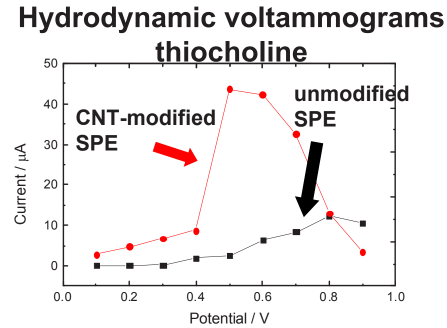
Electrochemical Characteristics of Thiocholine at the CNT-Modified SPE





- Current response for CNT-modified SPE is much higher.
- CNT can electrochemically catalyze the oxidation of the enzymatic product thiocholine, enhancing amperometric signal.

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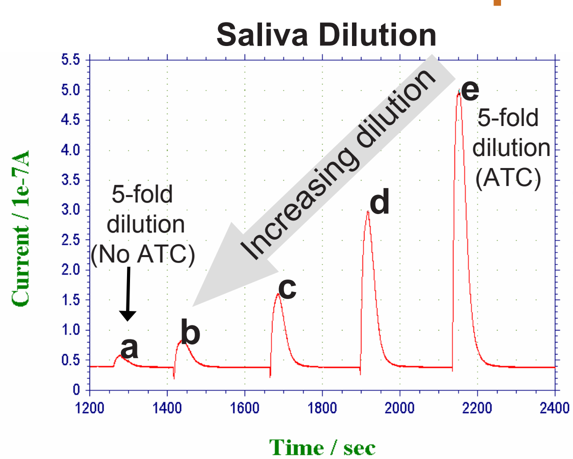
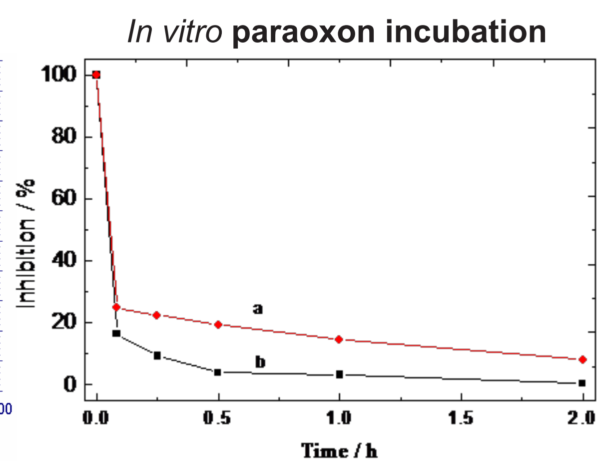
Rat Saliva ChE Response





- Saliva dilution from 5 to 40-fold, enzyme activity still detected (b→e).
- Low background (i.e. electroactive substances) in matrix (a).
- Paraoxon + 10-fold diluted saliva:
  - a) 0.7nM paraoxon (~80% inhibition at 0.5 hr)
  - b) 7 nM paraoxon (~97% inhibition at 0.5 hr)

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Summary: Carbon nanotube (CNT), screen-printed electrode (SPE) for ChE enzyme activity

- The CNT-based electrochemical sensor is simple, inexpensive, and sensitive for detecting ChE enzyme activity in saliva.
- Technique can be extended to other biological samples (i.e. plasma and RBC).
- *In vivo* animal validation studies will establish the sensitivity relative to more conventional assays (i.e. Ellman).

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Nanoparticle-based electrochemical immunosensor for phosphorylated AChE

- Nanoparticle-based electrochemical immunosensor for detection of phosphorylated (i.e. inhibited) AChE.
- Zirconia (ZrO_2) nanoparticles used as selective sorbent for phosphorylated proteins.
- Quantum (QD) dots (CdS) used as tags to label monoclonal anti-AChE antibody to quantify immunorecognition event.
- Captured QD determined by SPE electrochemical stripping analysis (Cd) after acid-dissolution step.
- Initial studies focused on ‘proof of principle’ for detection of organophosphate-modified human AChE *in vitro*.

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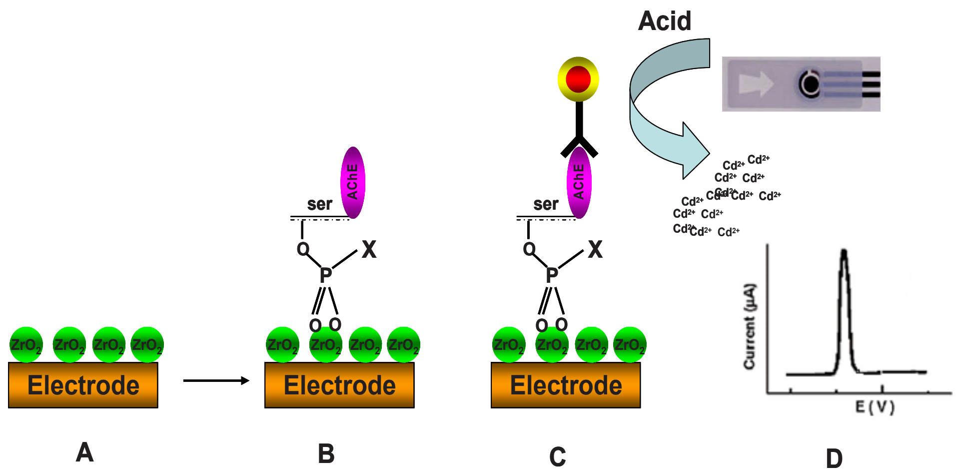
Quantum Dot Electrochemical Immunosensing: Phosphorlated AChE



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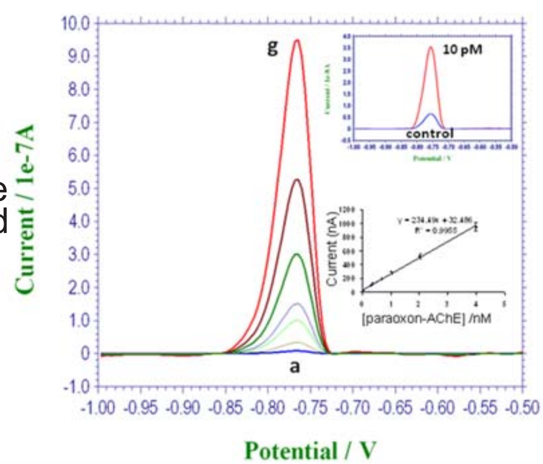
Performance of the Immunosensor (optimal conditions)

- Monoclonal anti-AChE recognized both AChE & phosphorylated-AChE.
- Paraoxon utilized with human AChE to produce adduct.
- Performance evaluated over range (.01 nm → 4nM) of phosphorylated AChE concentrations.
- Human plasma AChE ~ 0.12 nM (8 ng ml^{-1})
- A minimum 15% inhibition of plasma ChE would yield 0.018 nM and would be quantifiable.



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Summary: Nanoparticle-based electrochemical immunosensor for phosphorylated AChE

- Nanoparticle-based electrochemical immunosensor has potential to measure phosphorylated AChE as a biomarker.
- Demonstrated ability to detect phosphorylated AChE in complex biological matrices (data not shown).
- ZrO_2 shows promise as a good capture agent for phosphorylated proteins.
- Additional *in vitro* and *in vivo* validation studies are needed to establish performance criteria.

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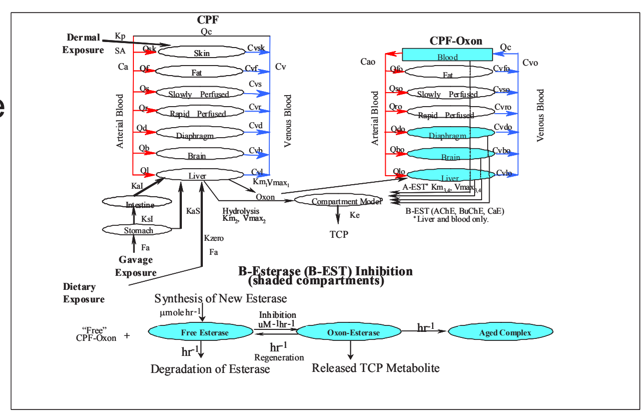
Physiologically based pharmacokinetic and pharmacodynamic (PBPK/PD) modeling

- PBPK/PD models have been developed for organophosphorus insecticides (chlorpyrifos, CPF).
- Capable of simulating target tissue dosimetry and biological response (i.e. ChE inhibition).
- Utility of model:
  - Cross species extrapolation (rat-human)
  - Integrates all routes of exposure (oral, inhalation, dermal)
  - Can simulate broad range of scenarios (repeated dosing, dietary intake, variable exposures)



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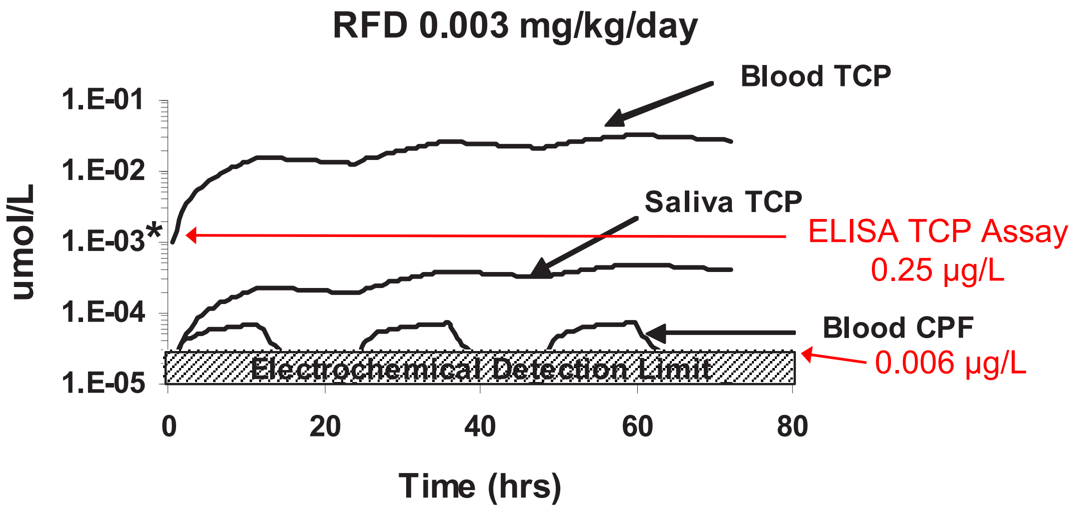
Pharmacokinetic Analysis



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Future Direction/ Conclusions…

- Laboratory validation studies
  - *In vivo* animals
  - *In vitro* human tissue
- Engineer into field deployable unit
- Design and conduct field validation studies

Conclusion

The development of portable nanotechnology-based electrochemical sensors has the potential to meet the needs for ***low cost***, ***rapid, high-throughput*** and ***ultrasensitive*** bioassays for biomonitoring an array of chemical markers.

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Acknowledgements

- Yuehe Lin PhD -Sensor development
- Jun Wang PhD -Sensor development
- James Campbell PhD -Bioanalytical chemistry
- Torka Poet PhD -Pharmacokinetics metabolism
- Jordan Smith PhD -Post-doctoral scientist

Grant Support

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- NIH/NINDS -U01 NS058161
- DOE -DE-AC05-76RL01830

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D.R.E.A.M.
WORKSHOP

Surface Sampling of *Bacillus* spores

NIOSH DREAM Workshop

Surface Sampling/Biomonitoring Breakout Session

November 13, 2008

Jayne B. Morrow, PhD

Acknowledgments

- **Kenneth D. Cole, PhD, Sandra Da Silva, PhD**
  Bioassay Methods Group
  Biochemical Science Division
- **Andy Persily, PhD**
  Indoor Air Quality and Ventilation Group
  Building Environment Division
- **Steven Choquette, PhD**
  BioaAssay Methods Group Leader
  Biochemical Science Division
- **Laurie E. Locascio, PhD**
  Chief, Biochemical Science Division
- **Bert Coursey, PhD**
  Department of Homeland Security

Efforts in Standards for Biological Countermeasures

Standards

Detection | Testing/ Sampling | Guidance | Training

Reference Materials

Training Materials

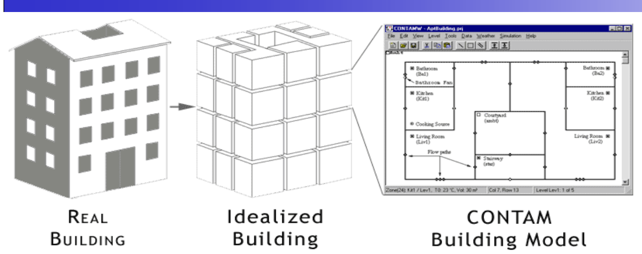
ASTM E2458 /AOAC

Standard Sampling Methods
Decontamination

Surface Sampling Validation
CDC and EPA

Sampling Procedures for First Responders

ASTM E2458/AOAC Standard effort Led by Laurie Locascio



CONTAM/VSP Modeling Software: Andy Persily at BFRL, Greg Piepel and Brent Pulsipher at PNNL

- Produce Guidance for the Sampling of Nonvisible Surface Contamination
- Develop a strategy for determining the extent of contamination and decontamination effectiveness

Sampling Visible Powders

The Goal: To develop the first US National Standard for collecting suspected biological agents.
The Motivation: Motivated by 2005 GAO report calling for validated methods for collecting suspected biological agents.
The Purpose: Reduce exposure risk, minimize on site sample consumption, reduce variability (sample handling and analysis).
The Scope: Collection of visible powders, credible biological threat for all biological agents from solid, nonporous surfaces, dispersed in a limited area

<u>ASTM E2458 /AOAC Standard</u>

Includes
- Response Coordination
- Field Screening
- Bulk Powder Sample Collection
- Transportation and Packaging

Bulk Powder Collection

Sterile plastic laminated card used with swab in “broom and dustpan” collection approach

Produces at least 2 samples that are transported to LRN (dry swab in tube, bulk powder in tube)

VSP Work Group

Validated Sampling Plan Work Group is a **DHS led multi-agency work group** set up to address the GAO request.

In a 2005 report titled **Anthrax Detection: Agencies Need to Validate Sampling Activities in Order to Increase Confidence in Negative Results (GAO-05-251),** the Government Accountability Office (GAO) recommended that “to improve the overall process for detecting Anthrax and to increase confidence in negative test results…[DHS] ensure that the overall process of sampling activities, including methods, is validated so that performance characteristics, including limitations, are clearly understood and results can be interpreted.”

The whole sampling process is currently under validation by the CDC, EPA, FBI, NIST, DOD and other agencies.

Current Sampling Methods: Wipe and Swab Procedures

- Deposition method: aerosolized[a,b] (95% Ethanol)
- Wetting agents: Water[a,b] (PBS)
- Controlled Substrata: stainless steel[a], painted wallboard[a]
- Wipes: rayon/polyester blend[a], rayon[b]
- Extraction from Wipe: sonication[a], vortexing[b]
- Report +/- Growth[b], reference coupons[a,b]

Wipe Efficiency Ranges from 7 to 87%

[a]Brown, G. S., R. G. Betty, et al. (2007). "Evaluation of a Wipe Surface Sample Method for Collection of Bacillus Spores from Nonporous Surfaces." Appl. Environ. Microbiol. 73(3): 706-710.

[b]Sanderson, W. T., M. J. Hein, et al. (2002). "Surface Sampling Methods for Bacillus anthracis Spore Contamination." Emerging Infectious Diseases 8(10): 1145-1151.

Challenges in Surface Sampling Methods

Spore Materials

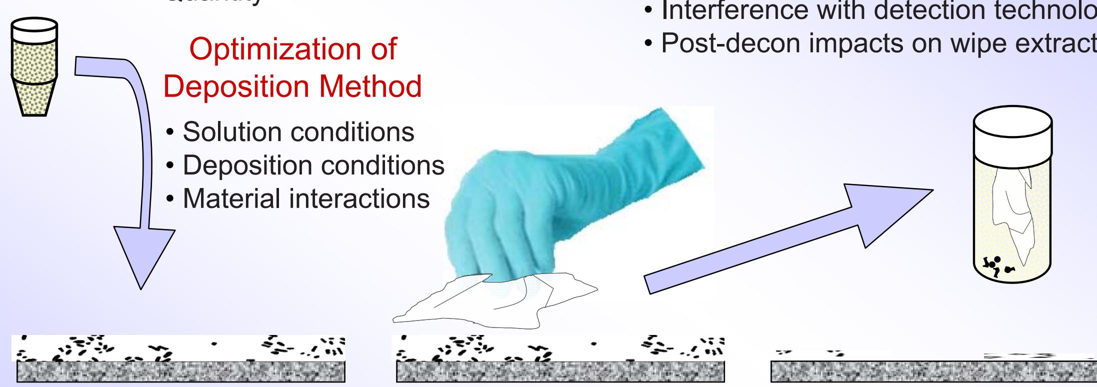
- Reaerosolization
- Suspension stability
- Viability
- Quantity

Integration with Detection Technology

- Optimization of removal from wipe
- Interference with detection technologies
- Post-decon impacts on wipe extraction

Optimization of Deposition Method

- Solution conditions
- Deposition conditions
- Material interactions

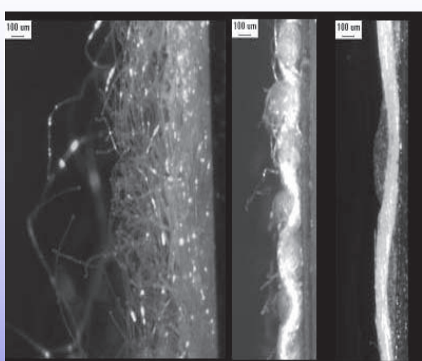


Optimization of Sampling Method

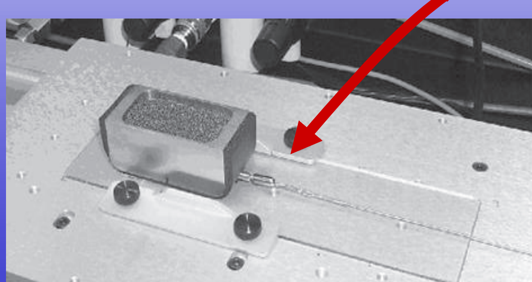
- Environmental Conditions
- Sampling pressure and velocity
- Mass balance on material for loss evaluation
- Wipe and substratum material interactions
- Post-decon impacts on wipe efficiency

Why Develop a Dynamic Wipe Efficiency Method?

- Standard method to evaluate wipe performance in a controlled environment
- Address some of the challenges in surface sampling standards development
- Means for validation of:
  - New materials
  - Integration with new detection technology
  - Address losses and identify gaps in current capabilities
  - Different contaminants and contaminants housed in matrix materials



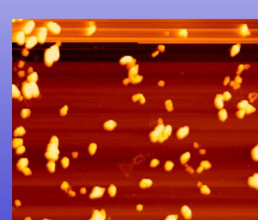
Nonwoven (Swiffer) Muslin PTFE



Crockmeter Testing Device

Standard Surface Sampling Method to Determine Dynamic Wipe Efficiency

Controlled sampling procedure to evaluate wipe performance in controlled environment



Spores Deposited on Control Surfaces

Modeled on the successful efforts of the
NIST Trace Explosives Group
Metrology of Explosive Particles and Vapors
Sampling, Detection, and Standards

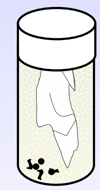
Standard Method for Dynamic Wipe Efficiency

1. Material Characterization
Well characterized aqueous spore suspension

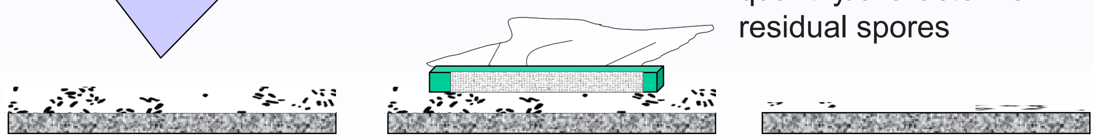
2. Deposition
Optically and AFM quantify/characterize deposited spores

3. Wipe Sample
Wipe surface using crockmeter in environmental chamber

4. Extraction
Enhance extraction efficiency with solution chemistry manipulation



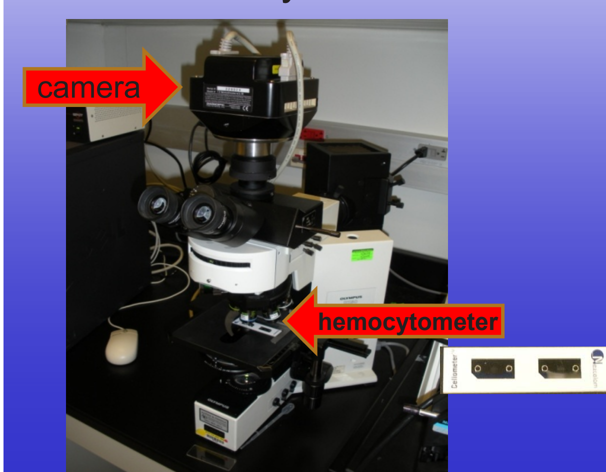
5. Performance
Optically quantify/characterize residual spores



Material Characterization: Spore Quantification

Direct Counts of Preparation Purity

Phase contrast microscopy used to manually count spores on a hemocytometer

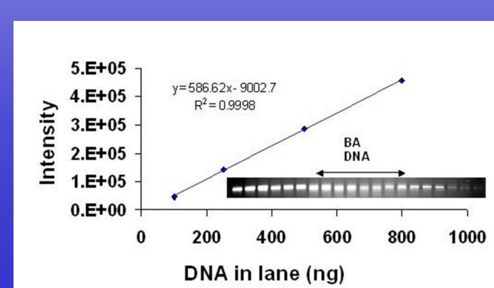


Viability Determination

LB agar plates were spread using serial dilutions and colony forming units (cfu)

DNA Quantity

PCR and gel electrophoresis are used to DNA concentration

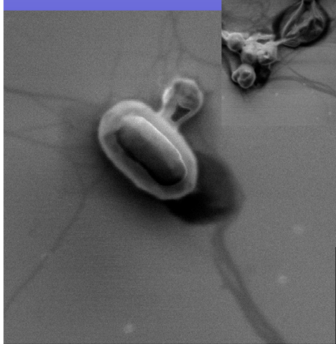


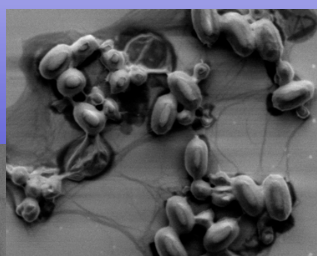
Material Characterization: Spore Aggregation

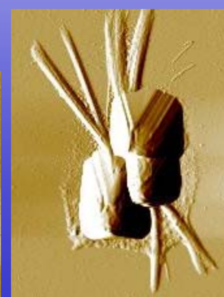
Measurements to aide in reference material production and understanding adhesion of spores to surfaces

- Surface Charge
- Hydrophobicity
- Particle size and morphology

Colloid stability theory to understand aggregation and surface association

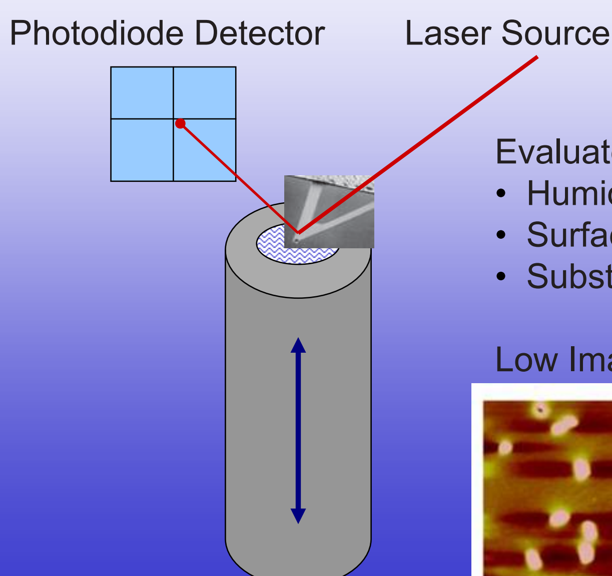






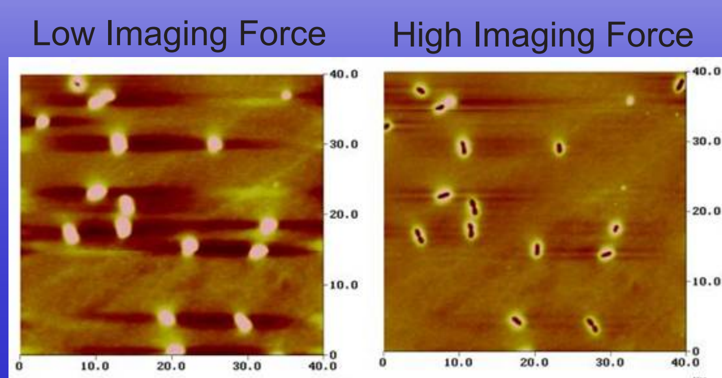
Collaboration with J. Rampersad and D. Ammons from the UTPA and R. D. Holbrook at NIST AML

Deposition Technique: Evaluate by Contact Mode AFM



Evaluate Sampling Force Required Given:

- Humidity (RH of 40 - 90%)
- Surfactant (H_2O, volatile Buffer, ± Tween 80)
- Substratum (Glass, SS, Teflon)



Surface Sampling Test Parameters

- Deposition method
- Number of sampling passes
- Substrata: stainless steel, copper, aluminum, glass, Teflon
- Wipes:
  - Woven: cotton, polyester
  - Nonwoven: Versalon (rayon/polyester blend)
- Environmental factors
  - Relative humidity (40 to 90%)
  - Wetting Agent (DI water, PBS, ± Tween 80)
  - Temperature
- Spores embedded in matrix materials
  - Urban particulate dust
  - Arizona dust
  - Skin cells

Overview of Efforts at NIST

Measurement Services for Characterized Reference Materials

Detection Technology Evaluation and Surface Sampling Science

- DNA Signatures
- Viability Determination
- Optical Characterization
- Surface Chemistry
- Suspension Stability

Guidance document for 1st Responder Technology Selection

Integration of Sampling with Detection Technologies

- DNA Signatures
- Antigenic Signatures
- Viability Determination
- Optical Characterization

Surface Sampling Science

ASTM method for sample collection

ASTM method for wipe efficiency

Guidance document for 1st Responder Surface Sampling

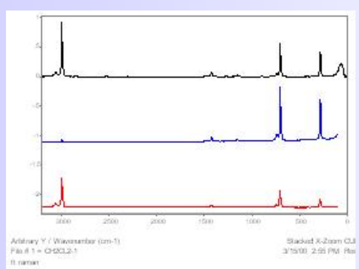
Biological Detectors for First Responders

	Representative Technologies	Basis of the Technology
Screening Devices	Hand Held Assays, Nonspecific particle detection	Antigens, Nucleic acid signatures (**non-PCR**), Proteins Light Scattering/Fluorescence
Field Deployable Detectors	PCR Kit or Integrated PCR Immunological kit	Antigens, Nucleic acid signatures
Autonomous Monitors	Automated PCR, Aerosol detector	Nucleic acid signatures, Spectral properties (fluorescence, Raman)
Laboratory Analysis and Forensics	Standard methodologies (LRN), MIDI, Spectroscopy (FTIR, Raman)	DNA specific (PCR), Fatty Acid, Immunological, Culture Light Spectroscopy

Standards Development for Biothreat Detection by First Responder Community

- Spore reference materials for hand held detection assays
- Spore DNA reference materials for PCR based assays
- Raman spectroscopy reference materials and R&D related to reference material development

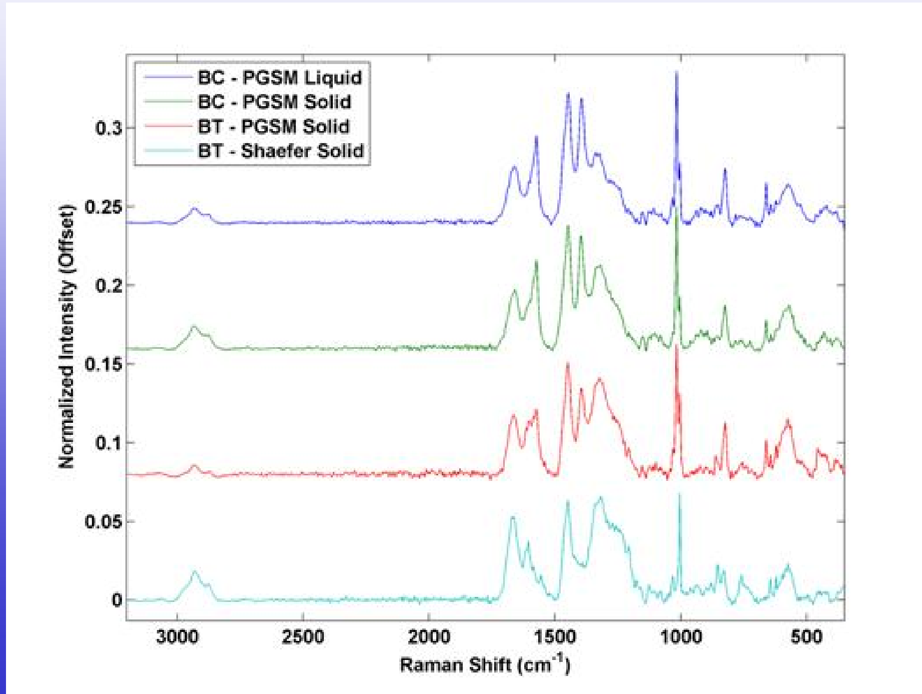
Raman SRM Development



Raman Spectroscopy provides sample identification in real-time without sample preparation and through common containers.

Development of SRM's for calibration of both Raman Shift (x axis), Intensity (y axis) and Resolution.

Raman Spectroscopy- Growth Media Impact and Strain Variation



~60 mW, 785 nm excitation through a 50X objective on our Renishaw system

Spore/DNA RM Development

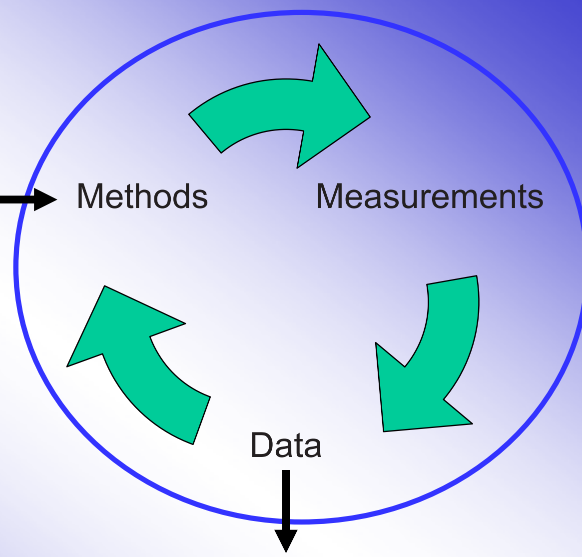
Development of Reference Materials for calibration of detector sensitivity and specificity.

Measurements to support RM development:

- Storage condition impacts on long term stability of spore suspension viability
- Quantification of spore preps
- Spore suspension stability and aggregation factors

Measurement Services

Samples



Customers

- Biological Repositories
- Government Laboratories
- Manufacturing Companies
- Commercial Testing Laboratories

Certificates of Analysis to customers (values, uncertainty, methods and recommendations)

Collaborations with USDA and EPA

Future Efforts at NIST

- Improved methods for characterization of reference and training materials
- Measurement characterization of threats and rational selection of simulants and prediction of pathogen fate and transport
- Improved methods for detection or measurement of biological threats and threats in matrix materials including soils, particulate matrices
- Decontamination- data on disinfectants, improved disinfectants and methods for decon
- Sampling and integration of sampling with detection, decon and training on sampling methods

ACS Environmental Division Call for Papers

We would like to draw your attention to an upcoming symposium for the 238th American Chemical Society National Meeting in Washington DC from August, 16-20, 2009. This symposium within the Division of Environmental Chemistry is titled **"Detection and Sampling for Biodefense".** The official Call for Papers can be found at **http://www.environfacs.org.**

The purpose of this session is to foster innovative interdisciplinary approaches to studying the integration of biological detection and sampling technologies by attracting researchers with a variety of scientific backgrounds who are studying this and related topics. This session will present recent advances in (i) innovative quantitative or mechanistic detection technologies, (ii) measurement issues in the integration of detection technology with surface and aerosol sampling methodologies (ii) bioanalysis in complex and environmental matrices and (iii) surface chemistry contributions to detection and sampling efficiency. We are particularly interested in work that evaluates the challenges in detection of specific microbial pathogens and biotoxin analytes relative to the biodefense community. Presenters are required to submit a short abstract to the ACS by March 16, 2009, using the ACS on-line system (OASYS) at http://oasys.acs.org/. **OASyS opens on January 19, 2009 and closes March 16, 2009.** There is no requirement for an extended abstract.

Jayne B. Morrow, Ph.D. (jmorrow@nist.gov)
Biospectroscopy Group, Biochemical Science Division
National Institute of Standards and Technology
100 Bureau Drive, MS-8312
Gaithersburg, MD 20899

Jacky Ann Rosati, Ph.D. (Rosati.Jacky@epamail.epa.gov)
U.S. Environmental Protection Agency
National Homeland Security Research Center
E343-06, 109 T.W. Alexander Drive
Research Triangle Park, NC 27711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Next-generation metal analyzers based on nanomaterials for biomonitoring and environmental monitoring

NIOSH DREAM Methods Workshop
Session 6: Surface Sampling/Biomonitoring

November 13-14th, 2008

Wassana Yantasee, PhD, MBA
Pacific Northwest National Laboratory, Richland, WA
Materials Chemistry and Surface Research Group
Wassana.Yantasee@pnl.gov

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Goal

- **Goal:** To develop portable metal analyzers for biomonitoring and environmental monitoring of toxic metals
- **Targets:** Cd, Pb and Hg
- **Matrices:** Urine, saliva, blood, natural waters
- **Relevant range:** 0 to 100 ppb (μg/L)
- **Characteristics of next-generation metal analyzers:**
  - Are portable, field-deployable, and programmable
  - Require no sample pretreatment and are user friendly
  - Require short analysis time (3-5 min)
  - Are affordable and consume low power
  - Are able to detect multiple metals at once and as accurate as gold-standard ICP-MS
- **Sponsors:** CDC/NIOSH, NIH/NIEHS, DOE-EMSP

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Current state of metal analyzers

- ICP, ICP-MS, AAS are not portable, expensive, require samples to be sent to lab, and require trained personnel to operate
  - Lengthy turn around time for sample analysis (2-4 weeks)
  - $50-$100 per sample (per metal)
- Real-time analyzers are desirable (e.g., for timely removal of workers from hazardous conditions)
- On-site, affordable analyzers will enable better and more frequent monitoring of worker exposure by employers
- Available portable systems:
  - Portable XRF is not yet sensitive (in ppm or mg/L)
  - Chemical spot test kits are not quantitative
  - LeadCare systems are only for blood Pb
  - SafeGuard™ arsenic analyzer (based on ASV, only works waters, $35K a unit, 30min/sample, interfered by Cu)
  - Metal biosensors (using antibody to identify metals, 6-8 hrs/analysis)

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Electrochemical sensors for metal analysis

Issues of current electrochemical sensors:

- Most rely on Hg for metal preconcentration
- Chemically modified sensors (Hg-free) rely on
  - Addition of soluble ligands to samples (risk adding metal contaminants)
  - Ligands that are loosely immobilized on electrodes and depleted over time
  - Some use gold (metal peaks overlap), silver (small operating window), and bismuth (unstable film) electrodes
- All suffer from fouling by proteins, surfactants, and organic molecules (they adsorb on sensor surface and form insulating layer → low signal)
- Metals are readily bound to proteins and can't be detected accurately
- Most need sample pretreatment (e.g., acid digestion or extraction) to release metals from proteins and to prevent electrode fouling

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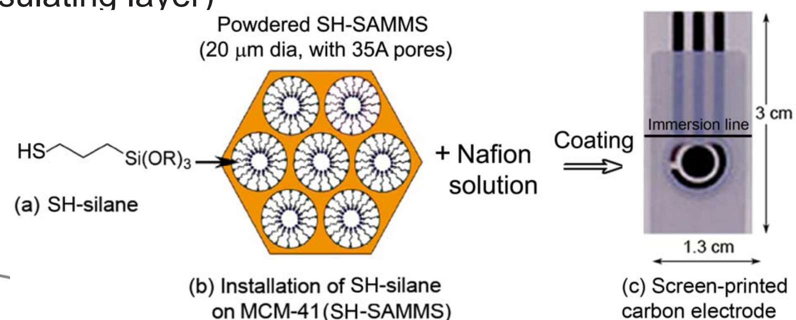
Our approach

1. Electrochemical sensors meet criteria for next-gen metal analyzers
2. Use novel sorbents to preconcentrate metals
   - must be able to compete with proteins for metals in urine
   - must have selectivity for target metals over non-target metals
   - ligands are covalently bound with substrate first (no ligand depletion)
3. Use Nafion polymer binder
   - Nafion immobilizes sorbents on sensor surface,
   - Nafion also prevents fouling (prevents protein adsorption and forming insulating layer)



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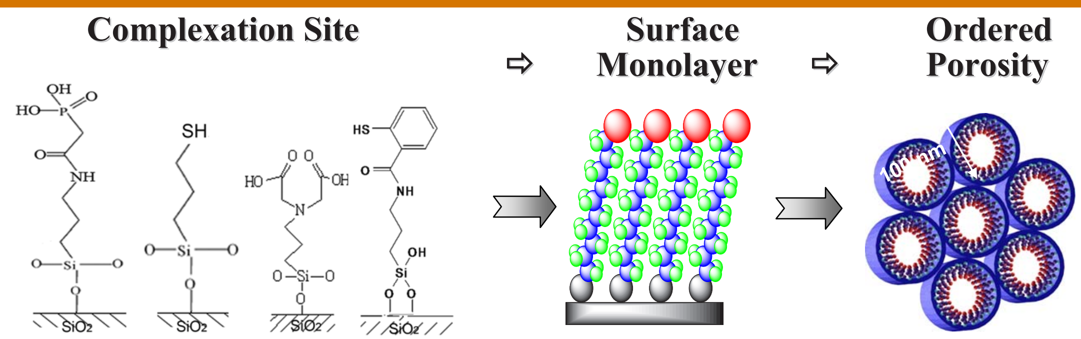
Two classes of nanomaterials:
Functional silica (SAMMS) and magnetic nanoparticles (NPs)



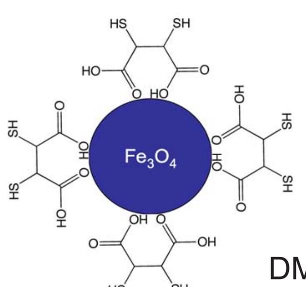
High affinity ligands

High capacity

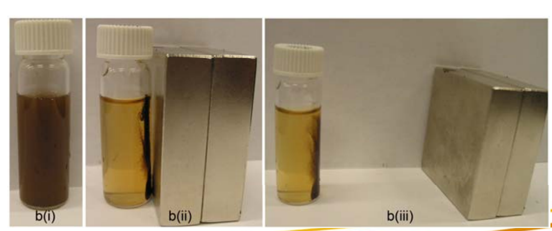
High surface area silica

Or

High surface area
mag nanoparticles



DMSA-NP



DMSA-NPs only turn magnet under magnetic field and can be removed out of solution

Yantasee et al., *Env Sci Technol*, 2007, 41, 5114

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Our research focus:
Functional nanomaterials for medical applications

Current projects employing advanced nanomaterials:

- At biomonitoring tools for worker exposure to heavy metals (CDC/NIOSH)
- For chelation therapies of heavy metals (NIH/NIEHS)
- For actinide decorporation in the event of dirty bomb (NIAID/Project BioShield)

New area:

- Sorbent dialysis (next-gen personal dialysis devices): to reduce dialysate from 120 L to < 1 L

PNNL's SAMMS made covers of journals and book

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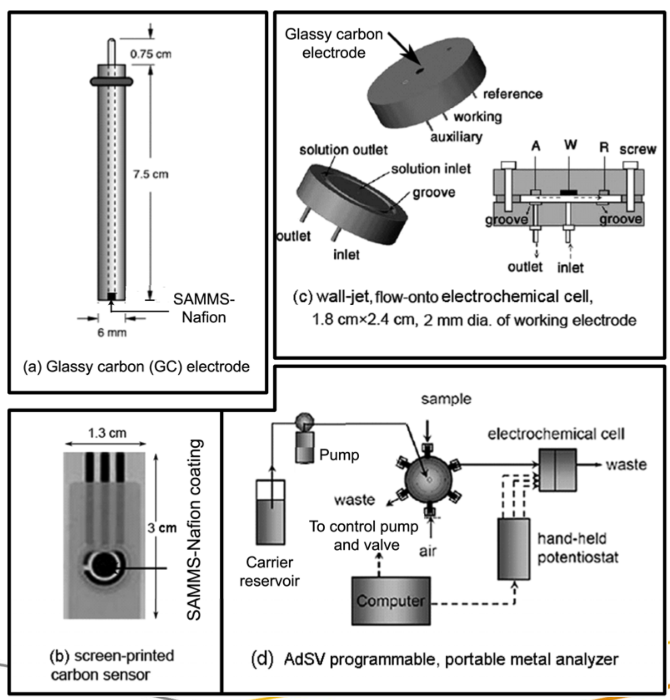
Sensor platforms:
Nanoparticles are immobilized onto electrode surface for metal preconcentration



3 platforms are used at PNNL

(a) Rod electrode for batch measurements

(b) Disposable electrodes for screening test

(c) Flow cell electrode

(d) Integration of flow cell electrode into an automated device

Yantasee et at., *EHP*, **2008**, 115, 1683.

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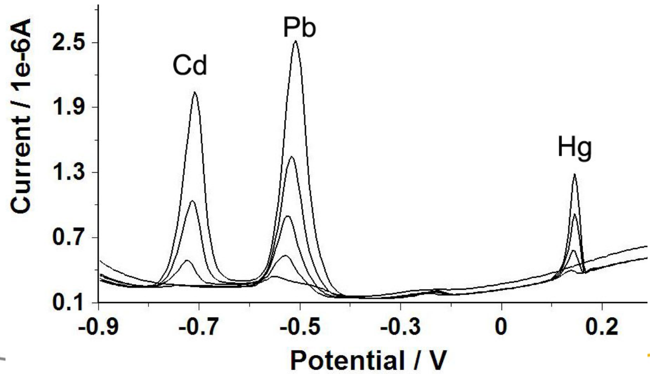
Detection principle: Two-step process

1. **Preconcentration step**: SH-SAMMS (coated on electrode tip) binds with metal ion (e.g., Pb(II)) by complexation (e.g., with -SH group). 1-3 min in samples
2. **Detection step:**
   2.1 Transfer the electrode to 0.1 M HCl. Accumulated Pb(II) is desorbed
   2.2 A -1.0V is applied immediately to convert Pb(II) to Pb(0) on electrode. 1 min
   2.3 Pb(0) is subsequently detected by an anodic stripping voltammetry:
   Pb(0) - 2 e- ↔ Pb(II), yielding Pb signal (current). 10s

Pb(II) do not re-bind to SH-SAMMS in acid, so the sensor does not need cleaning



- **Peak height** is proportional to metal concentration in solution
- **Peak position** identifies what metal:
  - Cd at -0.7V
  - Pb at -0.5V
  - Hg at 0.2V

▲ Detection of 10-100 ppb Cd/Pb, and 20-200 ppb Hg in river water at a SAMMS-Nafion electrode

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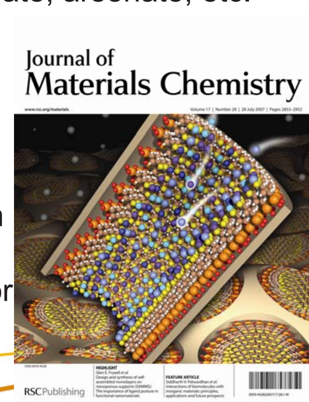
SAMMS-Nafion sensors

- SAMMS: created at PNNL for environmental applications (toxin removal)
- SAMMS: created by attachment of organic molecules on mesoporous silica
- Large surface area (> 500 m^2/g) → large capacity (600 mg Hg/g material)
- Organic ligands of SAMMS have been fine-tuned for heavy metals (Pb, Cd, Hg), lanthanides (Eu, Nd, Lu), actinides (Pu, Am, U), chromate, arsenate, etc.
- Take advantage of:
  - SAMMS as outstanding metal preconcentrator +
  - Nafion as antifoulting binder
  - SAMMS + Nafion is coated on electrode surface
  - 30 min air-dried to make rigid, stable, and porous film
- When coated with SAMMS-Nafion film, disposable sensor can last all day in urine
- The detection limits are improved by 1000-fold



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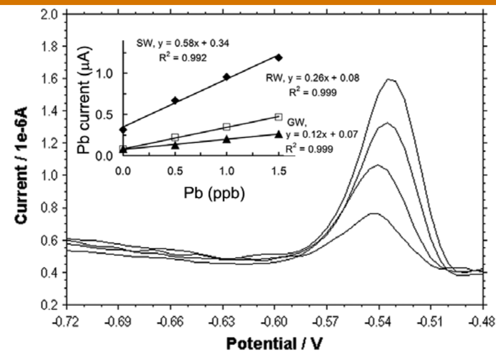
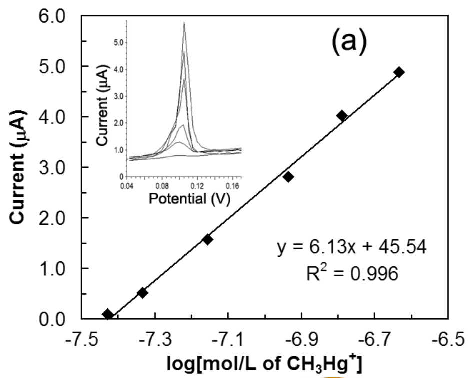
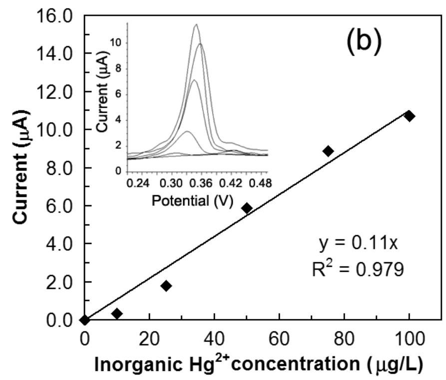
Example detection using SAMMS sensors



- 0-1.5 ppb of Pb in river, ground, and sea waters can be detected quantitatively
- No need for sample pretreatment (no filtration or pH adjustment)
- EPA's drinking water = 15 ppb Pb

Both methyl-Hg (a) and Hg^{2+} (b) can be detected at SAMMS-Nafion sensor





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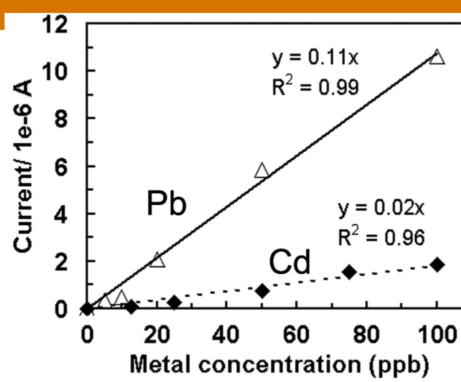
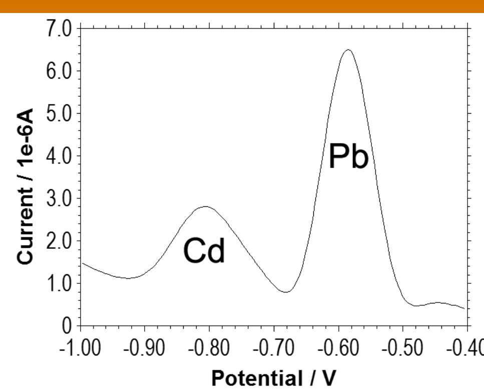
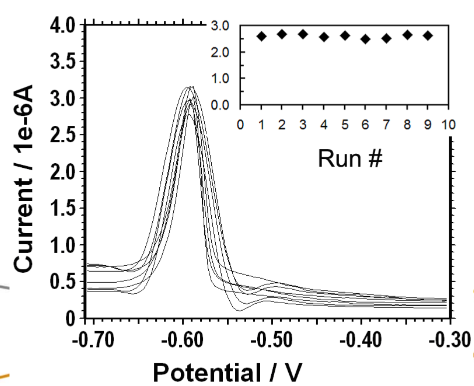
Example detection of SAMMS sensors





Pb and Cd could be detected simultaneously in urine without pretreatment



Excellent reproducibility in urine: %R.S.D = 2.6 (9 consecutive measurements of 50 μg/L Pb in human urine) at a SAMMS-disposable sensor

→ same with gold standard ICP-MS

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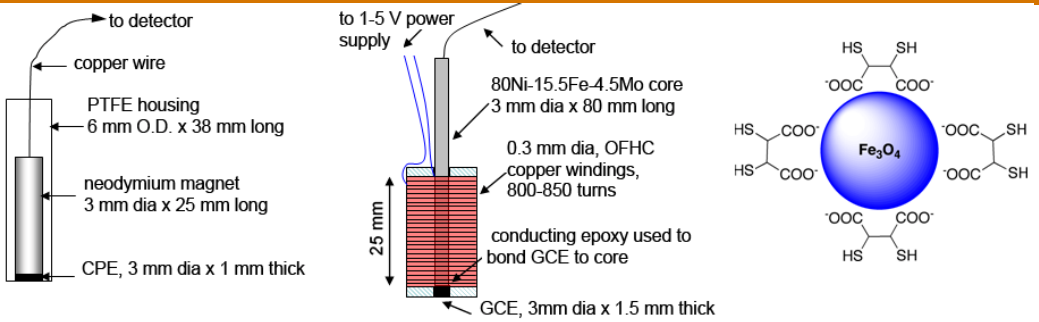
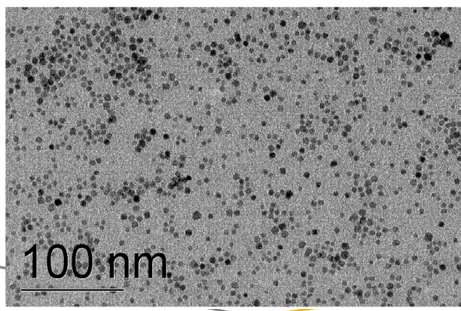
Magnetic and electromagnetic sensors



(a) Magnetic electrode (b) Electromagnetic electrode (c) DMSA-Fe_3O_4



- DMSA-NPs (c) are highly dispersible in solution
- Promote metal preconcentration in complex samples
- DMSA completes well with proteins for metals
- The metal-bound NPs are collected on surface of electrode (a or b) and voltammetrically detected
- The whole process takes ~ 90s

Yantasee et al., *Analyst*, **2008**, 133, 348

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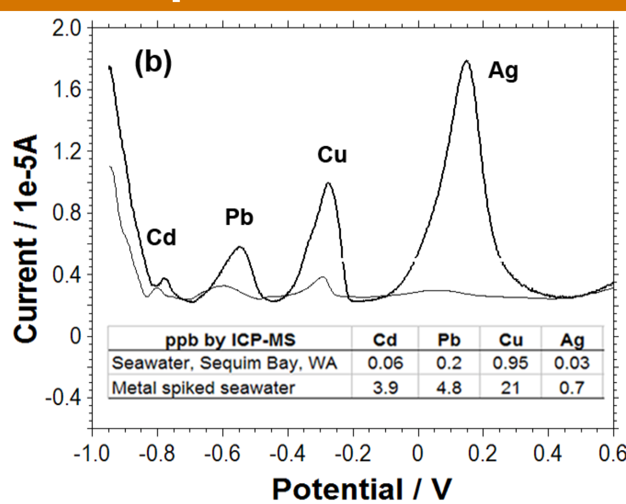
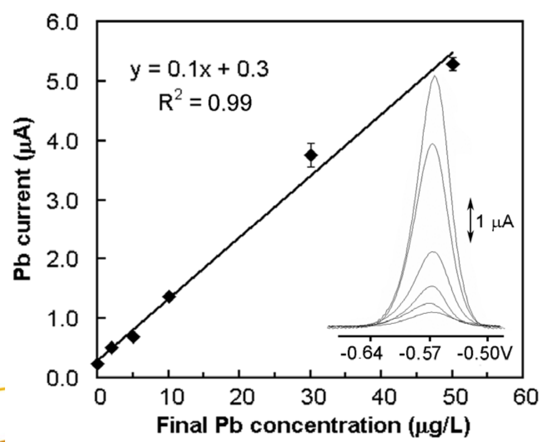
Example detection of magnetic NP sensors



ppb by ICP-MS	Cd	Pb	Cu	Ag
Seawater, Sequim Bay, WA	0.06	0.2	0.95	0.03
Metal spiked seawater	3.9	4.8	21	0.7

- Detection limits of metals in seawater are less than 1 ppb
- Background metals in seawater and river water can be detected
- No sample pre-treatment
- 3 min total analysis time

- 0-50 ppb urinary Pb could be quantitatively detected after 2.5 min
- Range is relevant to biomonitoring
- Analysis of 3 unknown urine samples yielded similar values to ICP-MS



Yantasee et al., *Analyst*, **2008**, 133, 348

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Summary: Two classes of nanomaterials for sensors

	SAMMS	Functional magnetic NPs
Advantage	- Withstand wide pH range (pH 0-9) - Small pore size exclude proteins from fouling the binding sites - Easily immobilized on the electrode surface using Nafion - Can be engineered into low-cost, easy to use, disposable strips	- Fully dispersible in solution - Once bound with metals, fast collected on magnetic electrode - Make very sensitive sensor in a short time (LDL < 1ppb in 2 min)
Application	- Urinary Pb and Cd detection - Cd, Pb, Cu, Hg, Tl, U, Eu detection in waters - No sample pretreatment - 3-5 min analysis time - < 5% error of 7-9 consecutive measurements of urinary Pb	- Urinary Pb detection - Cd, Pb, Cu, Ag detection in natural waters - No sample pretreatment - 2-3 min analysis time - 5% error of 7 consecutive measurements of urinary Pb
Patent application	"SAMMS-Nafion electrochemical sensor and method for making"	"Functional magnetic nanoparticle analyte sensor"

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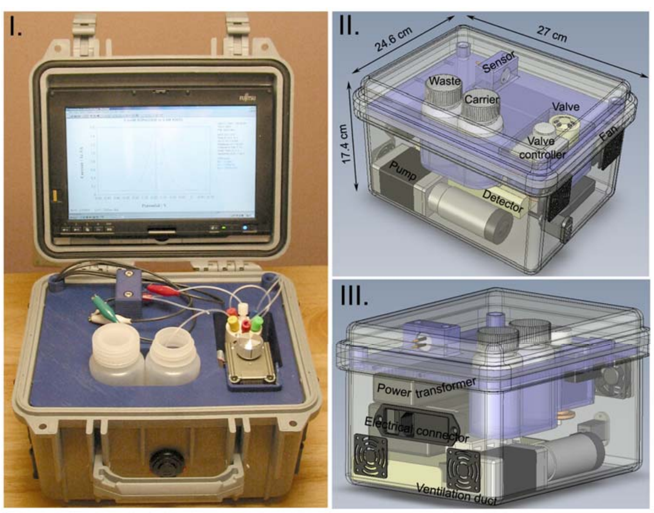
Prototype device for quantitative metal analysis



- A bit larger than a lunchbox
- Programmable
- Requires about 1.5 times the power of a typical laptop computer
- $10K per unit

- Plug-and-play feature allows different sensors to be easily exchanged for detecting a variety of toxins

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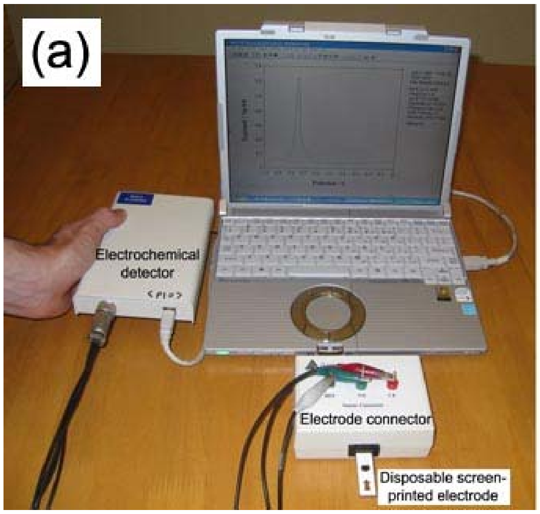
Disposable electrodes as screening tools



A portable sensor (a) system consisting of a disposable electrode strip (50 cent), a detector, an electrode connector, and a computer; all the components can be integrated into a single device similar to (b) the LeadCare device (ESA Biosciences, Inc.)

Conclusions

- Portable metal sensor systems have been developed with a built-in preconcentration function using advanced nanomaterials (SAMMS and functional magnetic nanoparticles)
- The surface chemistry provides the analytical enhancement
- Two sensor systems: (I) portable analyzers for quantitative analysis and (II) low cost, easy to use disposable sensors for screening test
- Low ppb detections of Cd, Pb, Hg, Cu, Ag, U, Eu, and Tl have been demonstrated
- Measurements are done directly after 2-6 min without sample pretreatment (nor protein fouling) in river water, ground water, seawater, and urine

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How our work is viewed:

- **Prof. Richard Compton of Oxford University, UK,** told *Chemistry World* about our NP sensors (Yantasee et al., *Analyst*, **2008**, 133, 348)

  ‘This is an extremely elegant piece of analytical work, neatly combining surface modification chemistry with magnetic particle separation and sensitive electroanalytical detection,'

  'The detection limits are impressive and, in particular, the challenge of working quantitatively on the substrates studied cannot be over-emphasized.‘

  Toxin test in a lunchbox, *James Mitchell Crow*, 22 February 2008, http://www.rsc.org/chemistryworld/News/2008/February/22020801.asp

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Future work

- Portable Cd and Pb analyzers for worker (urine) and work place monitoring (in air and on surface), which will benefit:
  - routine industrial hygiene air monitoring (must be done by employers as mandated by OSHA)
  - personal air monitoring
  - medical surveillance
  - NIOSH’s Health Hazard Evaluation (HHE)

- Portable analyzer for speciated mercury (Hg^{2+}, methyl Hg) in breast milk and blood for Hg biomonitoring (e.g., how Hg transfer from mother to infant)

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Acknowledgement

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- NIH/NIEHS, grant # R01 ES10976
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- Work is performed in EMSL, a DOE scientific user facility
- Staff:
  - K. Hongsirikarn
  - C. Warner
  - M. Warner
  - V. Sukwarotwat
  - K. Pattamakomsan
  - M.B. Toloczko
  - T. Sangvanich
  - G.E. Fryxell
  - J. Davidson
  - D. Choi
  - B. Chanhattakorn
  - R.A. Wiacek
  - C Timchalk
  - W. Chouyyok
  - W. Kiatkittipong
  - R.S. Addleman
  - J. Soelberg
  - Y. Lin

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Questions?

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WORKSHOP

Standardized Surface Sampling Methods for Metals

Kevin Ashley, Ph.D.

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Cincinnati, Ohio (USA)

National Institute for Occupational Safety and Health NIOSH

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Disclaimers

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention.

The findings and conclusions in this report are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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Overview

Background

- **Reasons for surface sampling**
- **Comparison to action levels or background**

Surface sampling techniques

- **Wipe, dermal, vacuum, etc.**
- **Attributes & limitations**
- **Available research & data gaps**

Discussion & summary

- **Performance data available (presented later)**
- **Examples of standardized methods**
- **Recommendations / improvements**

Introduction

Why Surface Sampling? Examples:

- Evidence of skin sensitization by exposure to beryllium particles
- Ingestion of lead from surface particles on hands
- Take-home exposures to metals in dust
  - Prevent exposure to metals on surfaces through exposure monitoring

Surface Action Levels for Pb, Be

Few metals have surface action levels established by regulatory agencies.

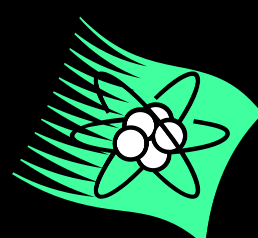
Lead and Beryllium are two elements having surface dust loading limits in the US.

Pb: EPA; Be: DOE

Beryllium surface compliance levels (DOE: 10 CFR 850)

Equipment release:

0.2 μg Be/100 cm^2



Housekeeping:

3.0 μg Be/100 cm^2

(But no information on sampling methodology)

"*Analysis by AIHA-accredited lab or equivalent*"

Surface action levels for lead
[40 CFR 745 (EPA 403 Rule), 2001]

Definition of dust-lead hazard (§745.6)

- floors (bare or carpeted): 40 µg/ft^2
- window sills (interior): 250 µg/ft^2

Clearance levels (§745.227)

- floors (bare or carpeted): 40 µg/ft^2
- window sills (interior): 250 µg/ft^2
- window troughs: 400 µg/ft^2

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EPA 403 Rule Pb Samples:

Samples of settled dust for risk assessment or clearance shall be collected:

- from horizontal surfaces underneath friction surfaces
- from floors (bare & carpeted)
- from interior window sills
- from window troughs (clearance only)
- *using wipes that meet ASTM E1792*

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Definition of Wipe Sample (40 CFR Part 745, §745.63):

Wipe Sample means a sample collected by wiping a representative surface of known area, as determined by ASTM E1728 [sample collection standard practice], or equivalent method, with an acceptable wipe material as defined in ASTM E1792 [Pb wipe specification].

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EPA 403 Pb samples, cont'd.

All samples shall be analyzed by a laboratory recognized under the National Lead Laboratory Accreditation Program (NLLAP).

[40 CFR 745.227(f)(2)]

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Surface sampling of metals

Consider:

Wipe samples (wet, usually)
Vacuum samples (various techniques)
Swab sampling (rare for metals)
Tape samples
Rinsates

Surface sampling of metals, cont'd

- Hard / smooth / nonporous surfaces
- Soft / rough / porous substrates
- Fragile substrates
- Oily / grossly contaminated surfaces
- Dermal sampling
- Bulk sampling

Surface Sampling Techniques

- *Wipe sampling*

  Wet: consider wetting agent

  Dry: consider sampling medium

- *Vacuum sampling*

  Alternative to wipe sampling

  Consider substrate to be sampled

Dermal & Bulk Sampling

- *Dermal sampling*

  Wipe, patch, tape & rinse methods

- *Bulk sampling*

  Use if there is gross dust buildup

  Soils / sediments

National Technology Transfer and Advancement Act of 1995 (NTTAA)

Public Law 104-113 (enacted 1996); directs federal agencies to:

(A) Use voluntary consensus standards in lieu of in-house procedures

(B) Participate in the development of relevant voluntary consensus standards

Advantages of the consensus standards development process

- Brings together people with a diversity of backgrounds, expertise, and knowledge
- Provides a balanced representation of interests at the standards-writing table (users, producers, general interest)
- Quality is enhanced by strict balloting and due process procedures, and requirements for method precision and bias / uncertainty statements
- Working group format promotes open discussion

ASTM International wipe sampling standard for metals

ASTM D6966,
Standard Practice for Collection of Settled Dust using Wipe Sampling Methods for Subsequent Determination of Metals

(Note: Established by voluntary consensus)

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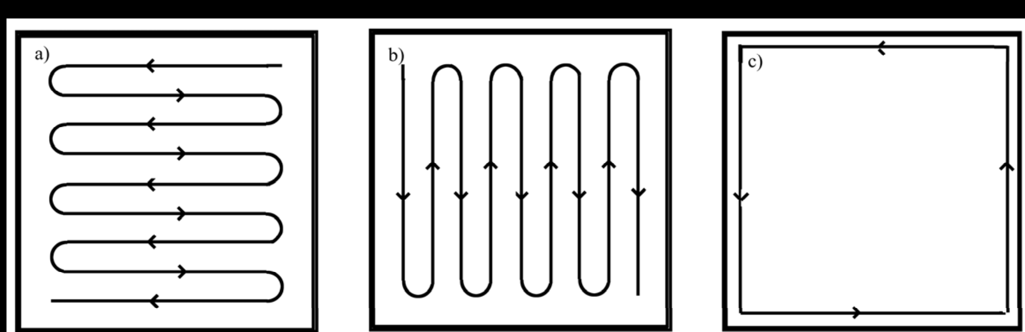
ASTM D6966 Requirements

- Individually packaged wipes; non-interfering materials; minimal metals background
- >75% collection efficiency (RTI, 1990s)
- Sampling scheme (100-cm^2 minimum sampling area):



ASTM E1792
Wipe Specifications

- Minimal background lead
- Ruggedness testing
- Uniform moisture content
- Individually packaged
- Dimensions & thickness
- Pb collection efficiency/ recoverability tests

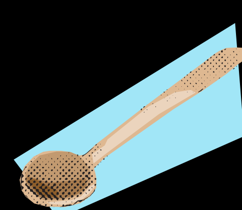
•Dry sampling methods

Vacuum cleaner method (carpets)
- ASTM D5438

Micro-vacuum sampling (rough / fragile / inaccessible surfaces)
- ASTM D7144

Dry wipe sampling (special cases)
- ASTM D7296

Bulk sampling
- ASTM & EPA methods



Vacuum sampling: Consensus standards

ASTM D7144

ASTM D5438

Dry wipe sampling

- ASTM D7296, Standard Practice for Collection of Settled Dust Samples using Dry Wipe Sampling Methods for Subsequent Determination of Beryllium and Compounds
- Use *only* if wet wipe sampling or vacuum sampling inappropriate
  [Also may be applicable to sampling radioactive elements]

Dermal sampling methods

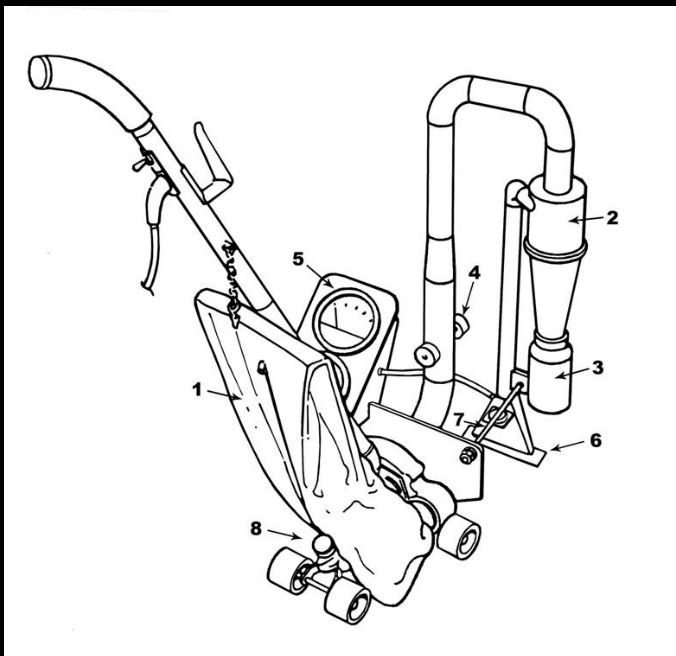
1. **Wet wipe**
2. **Patch sampling**
3. **Tape sampling**
4. **Skin rinsates**

(Photo by Dr. A. L. Sussell)

Surface sampling stds for metals (gov't & consensus)

Method	Media / device	Surfaces
OSHA ID-125G & ID-206	Wet or dry filter or wipe	Smooth / Hard; Dermal
NIOSH 9100, 9102	Wet wipe	Smooth; Dermal
ASTM D6966	Wet wipe	Smooth / Hard
ASTM E1216	Adhesive tape	Smooth
OSHA & NIOSH (several)	Patch or Rinse	Dermal samples
ASTM D5438	Vacuum cleaner	Carpets
ASTM D7144	Micro-vacuum	Rough or fragile
ASTM D7296	Dry wipe	Oily or fragile

ASTM D5438 – High-volume vacuum sampler (HVS3)



Dust sample collected in catch bottle (part #3)

(Figure courtesy of Dr. R. G. Lewis)

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ASTM D7144 Micro-vacuum sampler evaluation (Ashley et al., JOEH 2007)

Main sampler components:

- **Collection nozzle**
- **Cassette (& filter)**

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Dermal sampling: Need for voluntary consensus standards

- Recent review articles demonstrate lack of harmonization & consequent difficulty in data comparisons between different dermal exposure studies.
- New working groups in ISO TC 146 / SC 2 and ASTM International D22.04 will develop standardized procedures for dermal sampling.

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Bulk sampling methods

- Many published ASTM standard procedures: Scooping, coring; penetrometers, augers, etc. (www.astm.org)

  See, e.g.:

  (a) J.H. Morgan, Ed., *Sampling Environmental Media;* ASTM STP 1282 (1996)

  (b) EPA/OSW, *RCRA Waste Sampling Draft Technical Guidance* [EPA 530-D-02-002] (2002)

- Sample surface vs. subsurface: Distinguish anthropogenic vs. natural sources of elements.

Surface sampling of nonmetals

Recognize that other surface sampling methods for non-metals have been published by gov't and consensus standards groups; Examples:

- Drugs / pharmaceuticals
- Pesticides
- Biological agents

Summary

Focus here has been on available governmental and *voluntary consensus standards* for sampling of metals on surfaces, esp. wipe & vacuum collection methods.

- Performance data support some of the consensus standards (to be presented later).
- Bulk sampling methods are available (ASTM International; EPA) & well standardized.
- Identified need for standardization of dermal sampling methods (ISO, ASTM).

Acknowledgments

ASTM International Subcommittee D22.04 on Workplace Air Quality

ASTM International Subcommittee E06.23 on Mitigation of Lead Hazards

Beryllium Health and Safety Committee, Sampling and Analysis Subcommittee

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Surface sampling & analysis:
Examples from NIOSH work

Kevin Ashley, Ph.D.
CDC/NIOSH
Cincinnati, Ohio

Disclaimers

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention.

The findings and conclusions in this report are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

Examples for Pb, Be & Metals

1. Handwipe disclosing method for the presence of lead (qualitative)

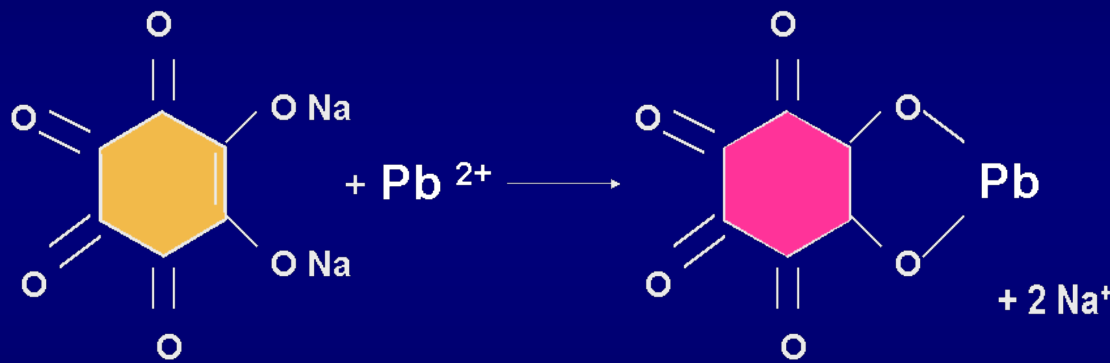
2. Determination of trace beryllium in wipe samples (quantitative)

3. Microvacuum sampling (performance data)

HANDWIPE DISCLOSING METHOD FOR THE PRESENCE OF LEAD*

*[*US Pat. 6,248,593*]

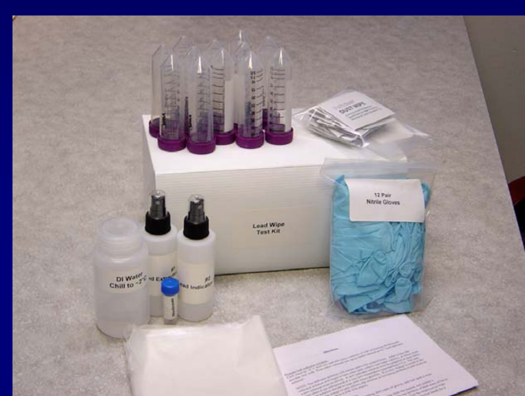
Sodium Rhodizonate – Lead Colorimetric Reaction



Sodium rhodizonate
(yellow / orange, pH < 7)

Lead – rhodizonate adduct
(pink /red)

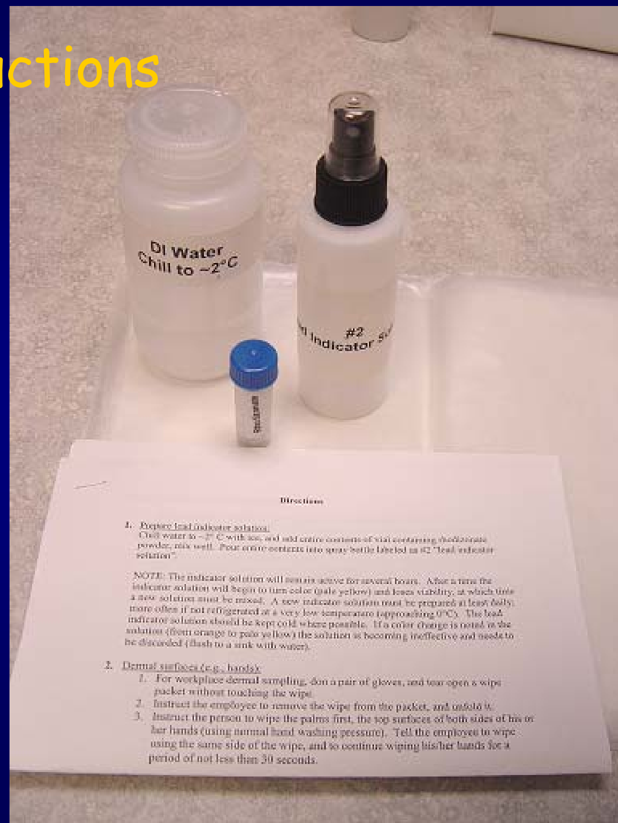
HANDWIPE DISCLOSING METHOD FOR THE PRESENCE OF LEAD



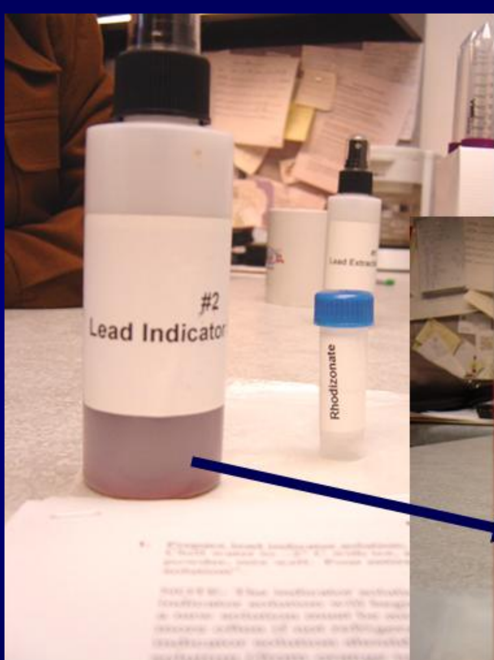
The kit includes:
1 instruction sheet
1 pre-weighed vial
of rhodizonate powder
12 handwipes
(10 samples and 2 blanks)
10 pairs of gloves
2 pre-labeled spray bottles
1 bottle of 105 mL DI water
12 50-mL sample collection tubes
10 sheets of pre-cut wax paper

1. Read the Instructions

Handwipe disclosing method for lead – Commercial product: "Full Disclosure"



2. Prepare the Pb indicator solution



Handwipe disclosing method for lead, cont'd.

(NIOSH Method 9105)

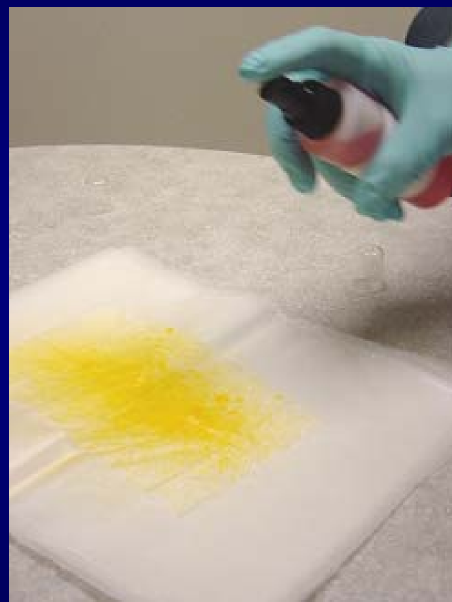
3. Wipe hands for 30 seconds

(use ASTM E1792 wipes)

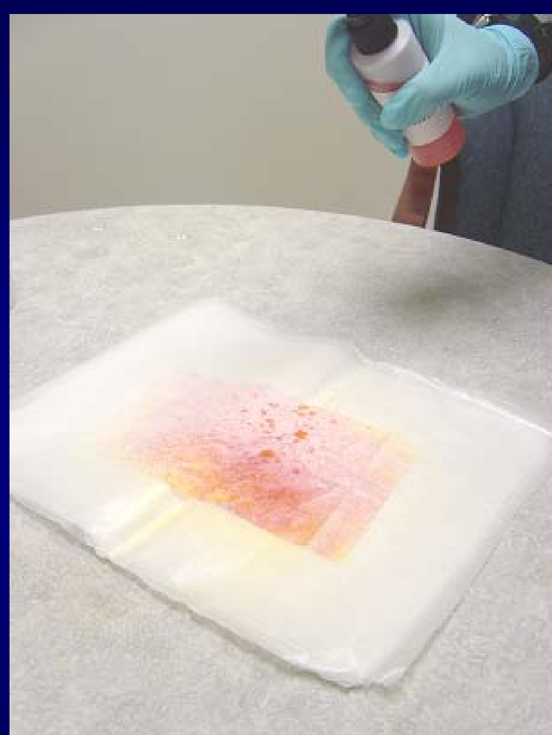
Handwipe disclosing method for lead, cont'd.

4. Spray 3 pumps of extraction solution (soln. #1) onto center of wipe

Handwipe disclosing method for lead, cont'd.

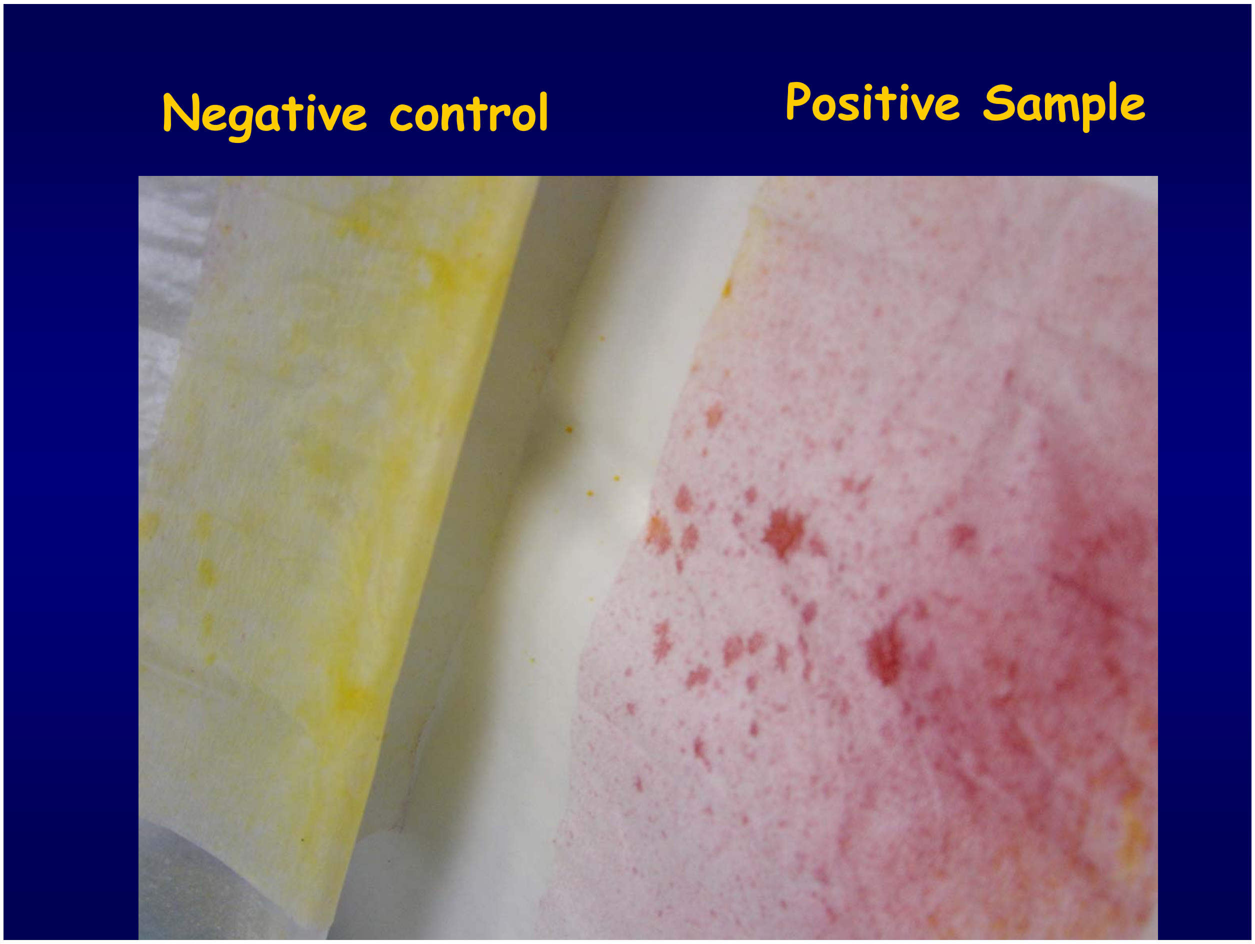


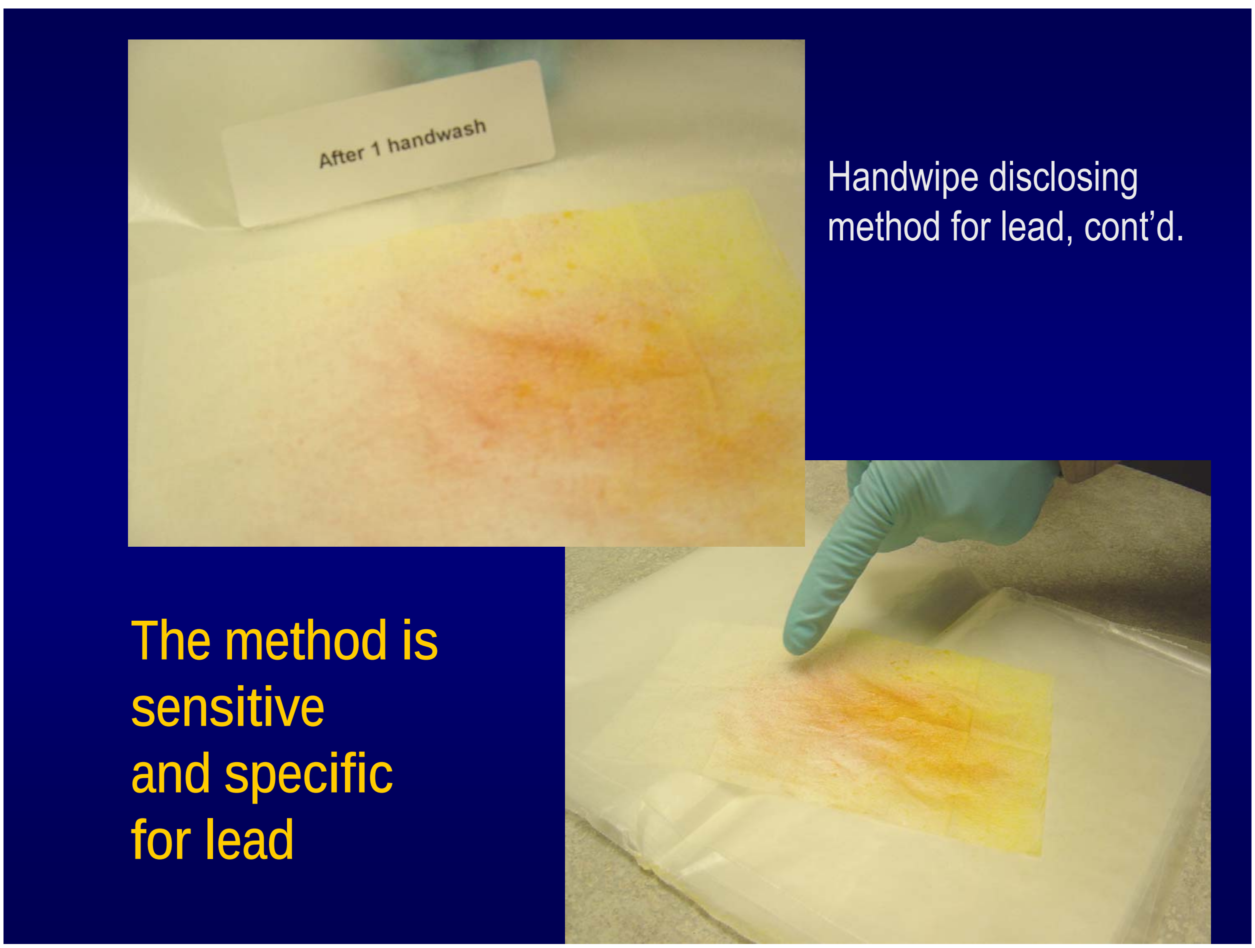
5. Spray 2-3 pumps of the disclosing solution (bottle #2) onto the center of the wipe



Handwipe disclosing method for lead, cont'd.

6. The presence of Pb is disclosed if the sample turns a pink to red color


Negative control
Positive Sample


After 1 handwash
Handwipe disclosing method for lead, cont'd.
The method is sensitive and specific for lead

Handwipe disclosing method for lead, cont'd.

Can be also be used to disclose the presence of lead on hard surfaces, e.g., Floors & WindowSills (pre-clearance), Shoes (take-home Pb), Car Interiors…

Wet wipe sampling of lead dust – Performance data (ASTM D6966)

Collection efficiency of Pb in dust from smooth surfaces (RTI, 1990s):
75-80% (1^{st} wiping); to >90% (3^{rd} wiping)

Collection efficiency of PbO dust from hands (NIOSH, 2000s):
55-60% (1 wipe, 30 sec per pair of hands);
to nearly 80% (3 wipes)

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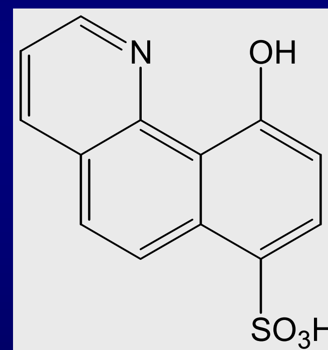
Trace beryllium measurement: New extraction – fluorescence method [ASTM D7202 / NIOSH 9110]

1. Sample collection using standard methods
2. Extraction of beryllium with dilute ammonium bifluoride, $(NH_4)HF_2$
3. Ultra-trace fluorescence measurement of beryllium with high quantum yield fluorophore (LOD <0.001 μg Be/sample)



Hydroxybenzoquinoline sulfonic acid (HBQS)

Trace beryllium measurement by extraction/ fluorescence method* – Performance data

Sample / media (n=no. of samples)	*Extraction method*	*Mean % recovery*	*RSD (%)*
Be (n=3)	mechanical	96	3.1
Be/Whatman (n=3)	mechanical	95	4.2
BeO (n=6)	mechanical	86	6.8
BeO (n=3)	heat (85 °C)	95	9.8
BeO/Whatman (n=15)	mechanical	82	5.6
BeO/Whatman (n=6)	heat (85 °C)	96	6.2

*[*Agrawal et al., JEM, 2006; Ashley et al., ACA, 2007*]

Dry wipe sampling of beryllium – Performance data* (ASTM D7296)

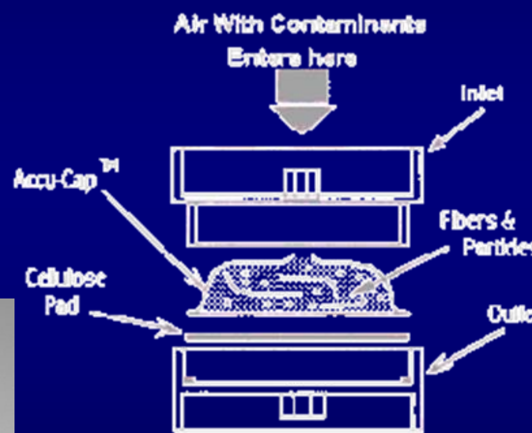
Sampling Media	% Recovery (RSD, %)
Wet PVA wipe	86 (7)
Dry PVA wipe	16 (54)
Wet cellulose filter	106 (9)
Dry cellulose filter	43 (25)
Wet smear tab	64 (13)
Dry smear tab	14 (22)

*[*Dufay & Archuleta, JEM, 2006*]

Micro-vacuum sampling: Performance evaluation* (ASTM D7144) – Substrates

*[*K. Ashley et al., JOEH, 2007*]

PVC inserts (Accu-cap^{TM}) for gravimetric analysis



Micro-vacuum sampling – Performance data (soft / rough surfaces)

Substrate material	**% Recovery (95% CL's), SRM 1579**	**% Recovery (95% CL's), SRM 1648**	**% Recovery (95% CL's), SRM 2583**
Industrial carpet	22 (10)	32 (14)	27 (8)
Plush carpet	36 (30)	34 (24)	41 (16)
Car seat material	31 (18)	49 (12)	49 (12)
Denim	45 (17)	37 (13)	55 (21)
Concrete block	64 (210)	69 (37)	87 (72)
Concrete block, painted	33 (14)	45 (21)	43 (26)

Micro-vacuum sampling – Performance data (hard / smooth surfaces)

Substrate material	% Recovery (95% CL's), SRM 1579	% Recovery (95% CL's), SRM 1648	% Recovery (95% CL's), SRM 2583
Glass	59 (11)	43 (10)	50 (14)
Tile	51 (27)	42 (35)	50 (18)
Steel	51 (10)	39 (9)	38 (21)
Linoleum	41 (21)	28 (10)	30 (15)
Vinyl	38 (18)	33 (13)	38 (18)
Wood	34 (19)	33 (10)	49 (23)

Micro-vacuum sampling – Cassette plus collection nozzles (soft / rough surfaces)

Substrate material	Approx. % collected, SRM 1579	Approx. % collected, SRM 1648	Approx. % collected, SRM 2583
Industrial carpet	35	57	50
Plush carpet	59	73	69
Car seat material	55	78	77
Denim	71	81	85
Concrete block	105	113	130
Concrete block, painted	55	72	59

Micro-vacuum sampling – Cassette plus collection nozzles (hard / smooth surfaces)

Substrate material	**Approx. % collected, SRM 1579**	**Approx. % collected, SRM 1648**	**Approx. % collected, SRM 2583**
Glass	87	88	76
Tile	77	88	85
Steel	72	83	71
Linoleum	71	70	56
Vinyl	64	74	65
Wood	55	76	75

Summary - Surface Sampling of Metals

Use standardized protocols and appropriate media to estimate surface contamination of:

Beryllium	*Lead*	*Chromium*
Arsenic	*Cobalt*	*Manganese*
Cadmium	*Silver*	*Molybdenum*
Aluminum	*Zinc*	*Uranium*
Mercury	*Tin*	*Nickel*

Acknowledgments

Lead handwipe method:

Eric Esswein, CDC/NIOSH

Beryllium fluorescence method:

Anoop Agrawal et al., Berylliant, Inc.

Mark McCleskey et al., Los Alamos Nat'l Lab

Microvacuum sampling method:

Greg Applegate & Tami Wise, CDC/NIOSH

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2008 NIOSH Direct-Reading Exposure Assessment Methods (DREAM) Workshop

November 13-14, 2008 @ Hilton Crystal City, Washington D.C.

Session 6
Surface Sampling/ Biomonitoring

Current NIOSH Efforts

Lead Wipes for surface sampling, NMAM 9105

Licensed to SKC inc as "Full Disclosure"

Current NIOSH Efforts

- Methamphetamine surface wipe methods, NMAM Draft 9106,9109,9111 by MassSpec with isotopic dilution.

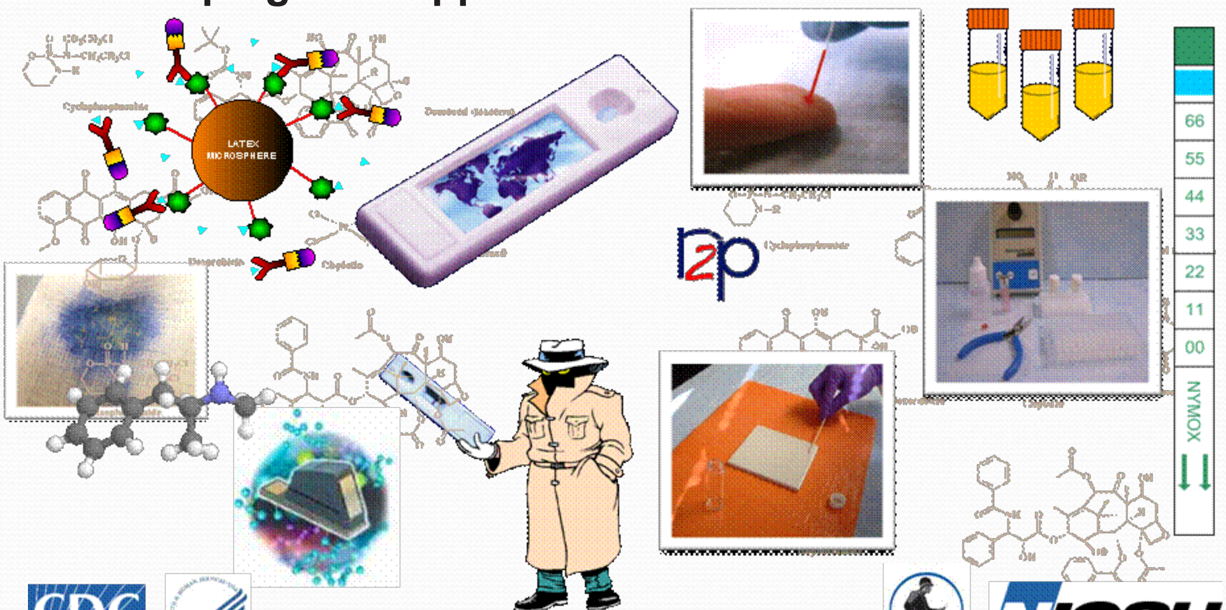
- 2 Direct Reading Methods, Colorimetric and Immunochemical. Licensed to SKC as “MethAlert” “MethChek”

Current NIOSH Efforts

Antineoplastic drugs on surface wipes Immunochemical detection

Current NIOSH Efforts

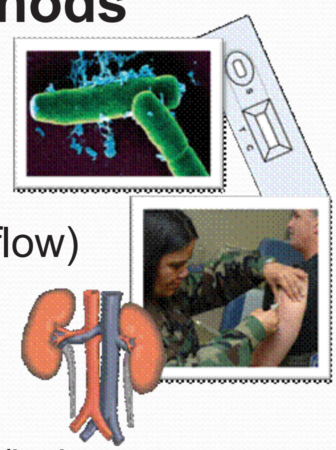
Developing New Applications for Common Platforms



Current NIOSH Efforts

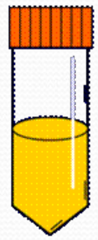
Development of new methods

- Anthrax vaccine status (lateral flow)
- β2-microglobulin in urine (lateral/vertical flow)
- Toxicity/Allergy (lateral/vertical flow)
- Cooperation with other federal /university/industry partners to evaluate new technologies



Current NIOSH Efforts

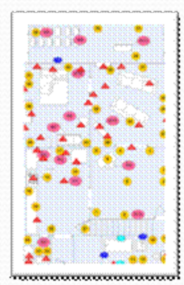
Application of commercial/clinical methods



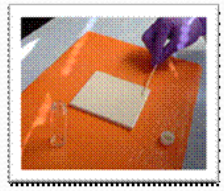
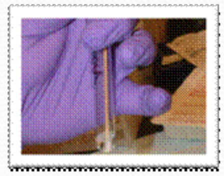
- Smoking status (lateral/vertical flow)
- CO monitors (exhaled breath /carboxyhemoglobin)
- Modification of test kits (pesticides)
- Point of Care (POC) diagnostics

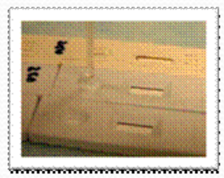
NIOSH DRM/DRI Uses

- Health Hazard Evaluations
  - Environmental Sampling, Biological Monitoring
- Exposure Assessment Studies
  - Environmental Sampling, Biological Monitoring
- Evaluation of Work Practices and Controls
  - Environmental Sampling, Biological monitoring



Challenges



- Limited REL/PEL for surface contaminants
- Limited Biological Reference Values (BRV)
- When is a qualitative measure good enough?
- What do quantitative numbers mean?
- How 'Direct' is direct reading? 1, 2, 3 steps

Workshop Aims

- What is the role for NIOSH in addressing DRI/DRM issues?
- Should NIOSH take the lead on a special DRI/DRM initiative?
- Identification of stakeholders/users: level of involvement.

Workshop Aims

- Types of DRI/DRM
- Current applications for DRI/DRM
- Obstacles to use of DRI/DRM
- Future applications/New Technologies
- Advantages/Disadvantages of particular instrumentation/methods

Workshop Aims

- Guidelines development: common criteria needed for multiple agencies.
- Specific NIOSH **N**ational **O**ccupational **R**esearch **A**genda (NORA) sector needs
- http://www.cdc.gov/niosh/nora

NORA

Wrap-up Session

Rapporteur Report

Hazard Session: Gases and Vapors

Monitor: Jay Snyder
National Institute for Occupational Safety & Health

Co-Monitor: Dr. Ted Zellers
University of Michigan

Rapporteur: Jason Ham
National Institute for Occupational Safety & Health

Invited Speakers

Dr. Dean R. Lillquist, (**Director, OSHA Salt Lake Technical Center**) - History of OSHA's use of direct reading instruments, the Agency's current applications, and possible future directions.

Mr. Mark Spence, (**Manager, North American Health and Safety Regulatory Affairs, Dow Chemical**) – Experiences and needs for direct reading methods and instrumentation from a broad chemical producer's perspective.

Mr. Mark Spence, (**International Isocyanate Institute**) -Current direct readings instrumentation and anticipated future challenges and needs for the polyurethanes industry.

Dr. Rebecca Blackmon, (**Technical Support Working Group**) - Instrumentation for gas and vapor detection currently under development.

Dr. Ted Zellers, (**Professor of Environmental Health Science, U of Michigan**) – Development of the micro gas chromatograph.

Mr. Jay Snyder, (**Sensor Project Officer, NIOSH**) - Application of MEMs sensors

Top Five Research Priorities

1. GC miniaturization – worth pursuing
2. Worker ability to measure own exposures
    a. Simple, cheap, high-throughput; inaccurate “ok”. More data!!
3. Refinement of existing technologies (improved sensitivity, selectivity)
    a. e.g., toxic gases, H_2S, CO (existing products not great).
4. Make devices multi-functional
    a. Chemicals, temperature, gps, heart rate, etc.
5. Development of self-calibrated systems (no need for gas transport)
6. DRI for HCHO, HF, chloramines (poultry), nicotine, R-N=C=O, needed
    a. Small-volume need, won’t be commercially successful
7. NIOSH-OSHA collaboration on transitioning new DRIs to compliance-acceptable status
8. Development of DRIs for unknown chemical components in mixtures
9. Worker empowerment (behavior modification, feedback to worker)

Direct Reading Instruments

(Usage & Implementation)

- What do you see as the most important impediments to more widespread use of DRIs?

- Where are they needed most?:
  1. Personal Monitoring for Compliance
  2. Personal Monitoring for Exposure Assessment
  3. Emergency Response
  4. Warnings for Life-Threatening Exposures

Rapporteur Report

Hazard Session: Aerosols

Monitor: Martin Harper
National Institute for Occupational Safety & Health

Co-Monitor: Pam Susi
CPWR

Rapporteur: Mark Methner
National Institute for Occupational Safety & Health

Top Five Research Priorities

1. Basic research into how instruments respond to aerosol characteristics
2. Invention/Continued development (esp. agent specific)
3. Develop consensus accuracy and validation standards
4. Develop standards for performance and use
5. Education and guidance on sector specific applications for existing products

Rapporteur Report

Hazard Session: Ergonomics and Vibration

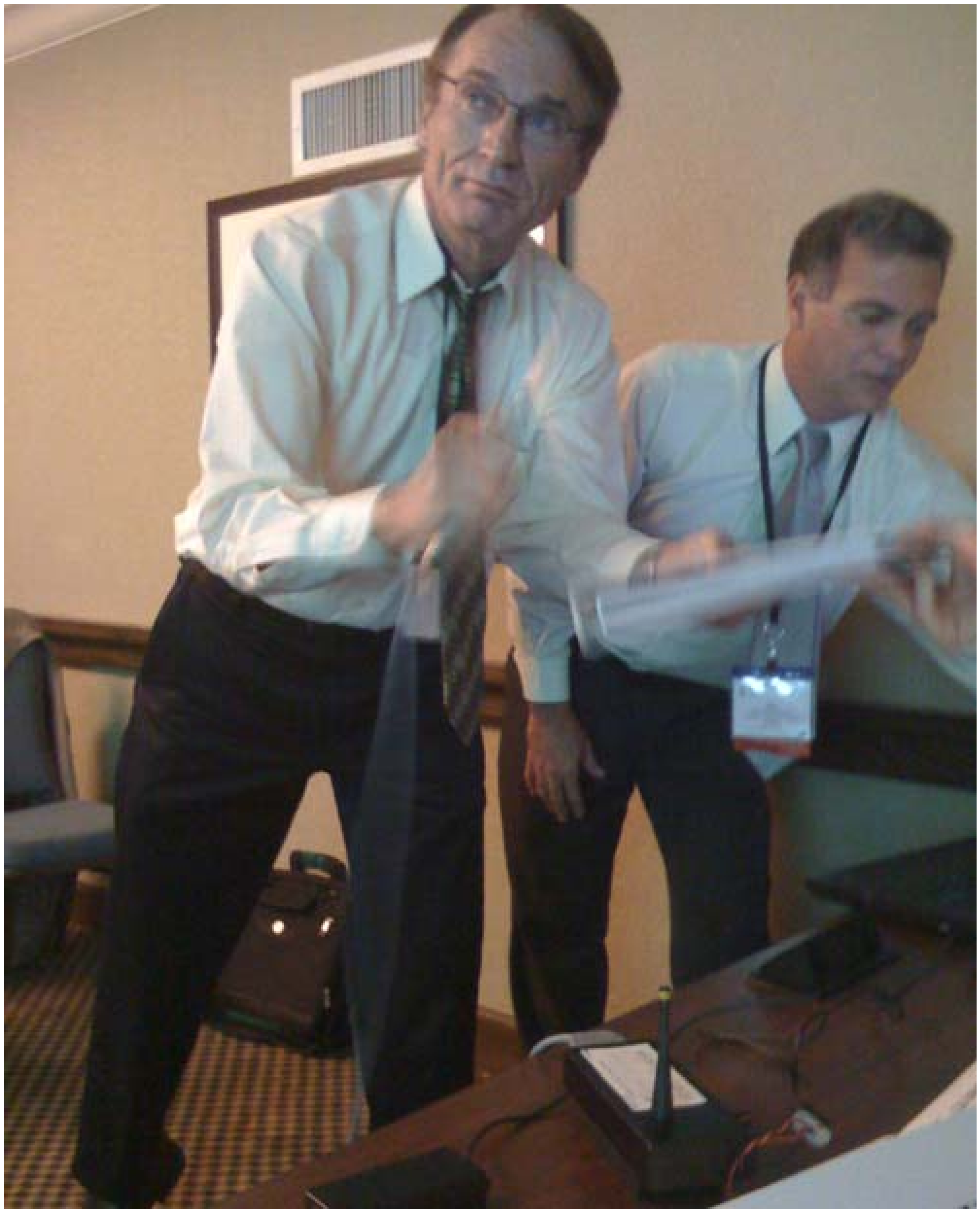
Monitor: Brian Lowe
National Institute for Occupational Safety & Health

Co-Monitor: Rob Radwin
University of Wisconsin

Rapporteur: Vern Anderson
National Institute for Occupational Safety & Health

Participants

Valerie Beck
Rebecca Bell
Frank Buczek
Linda Byrnes
Steven Chervak
Patrick Dempsey
Sunwook Kim
Brian Lowe
Raymond McGorry
Dinkar Mokadam
Gail Murphy
Vern Putz Anderson
Robert Radwin
Scott Robbins
Brian Roethlisberger
Thomas Waters
Daniel Welcome
Mike Wurm
Daniel Youhas



Importance of DRM for MSDs in Sectors

- National Academy of Sciences NRC/IOM 2001 Panel on Musculoskeletal Disorders in the Workplace

  RESEARCH AGENDA - METHODOLOGICAL RESEARCH

  1. Develop improved tools for exposure (dose) assessment.

  "Develop practical and consistent methods for objectively measuring physical stress (force, motion, vibration, and temperature) in the workplace and for quantifying occupational exposure (magnitude, repetition, and duration) with sufficient precision and accuracy."

- All 8 industry sectors have identified MSDs in their strategic goals (#1 or #2)
  - May be sector-specific environmental constraints

Working Definition

"These instruments provide objective *field-based* measurement of exposures *(force, motion, vibration and temperature)* that provide a method that indicates whether or not the exposures pose an occupational health or safety risk and if the *interventions* employed are actually providing the proper level of protection."

Unique Challenges of MSDs for DRM

- Exposure is the worker's mechanical interaction with workplace and tools (i.e. forces and motions)
- Hazard lies in the physical demands of the work
- Exposure measurement is indirect (chemical/physical agent model is not directly applicable)

Exposure Assessment for MSDs

- Job titles
- Checklists
- Observational-Based Analysis
- Biomechanical Modelling
- Instrumentation-Based Methods (limited)
  - Electrogoniometer (joint position)
  - Electromyography (muscle electrical activity)
  - Accelerometry
  - Force sensors
  - Video Exposure Monitoring

Top Research Priorities

1) Assess specific needs of customers for DRM (research-based vs. practitioner vs. worker)
2) Develop technologies to measure exposure dose
3) Investigate pathophysiological processes associated with exposures
4) Establish valid exposure assessment criteria (exposure limits)
5) Translate research into practical instruments for DRM

Attributes of Exposure Assessment

	Researcher	Practitioner	Worker
Reasonable cost	low priority	high priority	
Accurate	high priority	medium priority	
Unobtrusiveness	low priority	medium priority	
Real time			
Force and posture			
Repetition (frequency) magnitude			
Reliable			

Top Research Priorities

- **Assess researcher v. practitioner v. worker needs for DREAM in ergonomics**
  - On-site measurement (field)
  - Direct reading
  - Field measurement v. lab measurement
- **Need for technology to measure exposure (dose)**
  - Kinetics (force), kinematics (motion), vibration and cold
  - Repetition (frequency), magnitude, and duration
- **Understand pathophysiological processes associated with exposures**
  - Physiological responses to exposure (bio-monitoring)
  - Health monitoring instruments
- **Need for exposure assessment criteria**
  - Dose-response relationship
  - Inform decision making to prevent MSDs
  - Evaluate intervention effectiveness
  - Display and dissemination of information
- **Instruments for measurement and exposure assessment**
  - Measurement characteristics
    - Accurate
    - Reliable
    - Objective measurement and assessment procedure
    - Relationship to physical work
  - Usability of instruments
    - Manufacturability
    - Ruggedized
    - Worker and management acceptance
    - Reasonable cost
    - Training analyst and user
    - Speed of assessment
    - Real time
    - Unobtrusive

Rapporteur Report

Hazard Session: Noise

Monitor: Chuck Kardous
National Institute for Occupational Safety & Health

Co-Monitor: Rob Brauch
Larson-Davis, AIHA

Rapporteur: Terri Pearce
National Institute for Occupational Safety & Health

Noise Exposure Assessments

- Noise exposure instruments (Noise dosimeters and Sound Level Meters) are already direct-reading
- Standards (ANSI, ISO, IEC) exist for all instruments
- Regulations guidelines are well-established
- Several DRI/DRM issues still need development

Noise Instruments

Mixed or Combined Exposures

- Exposure to continuous, intermittent, and impact/impulse noise
- Exposure to chemicals or other hazards that can (additively or synergistically) cause hearing loss
- Issues related to different scenarios in which workers are exposed to mixed noise
- Non-auditory effects of noise exposure

Impulse/Impact Noise

- Impulsive noise more damaging than continuous noise
- No instrument capable of characterizing exposure or hazard on the market
- Direct-reading methods are not universally accepted
- Damage risk criteria based on incomplete data
- Rethink the damage risk concept

Worker Empowerment

- Will the worker modify behavior if they have access to direct, real-time, noise exposure readings?
- How to deal with occupational vs. non-occupational environments (musicians, soldiers, etc..)
- Inexpensive “dose” indicators are currently available

Testing, Evaluation, Certification

- Sound instruments must comply with current ANSI and IEC standards
- No entity to test and certify noise instruments today
- NIOSH was involved in the testing and certification of noise dosimeters in the 70’s
- Suggestion that NIOSH might want to consider testing and certification

Top Five Research Priorities

1. Re-examine the basis for current damage risk criteria
2. Determine the relationship between DRM metrics and achieving behavioral modification
3. New sensor technology (better microphones, acoustic manikins)
4. Metrics to quantify performance and economic impact of not having solid hearing conservation program
5. Develop a repository of exposure and risk data

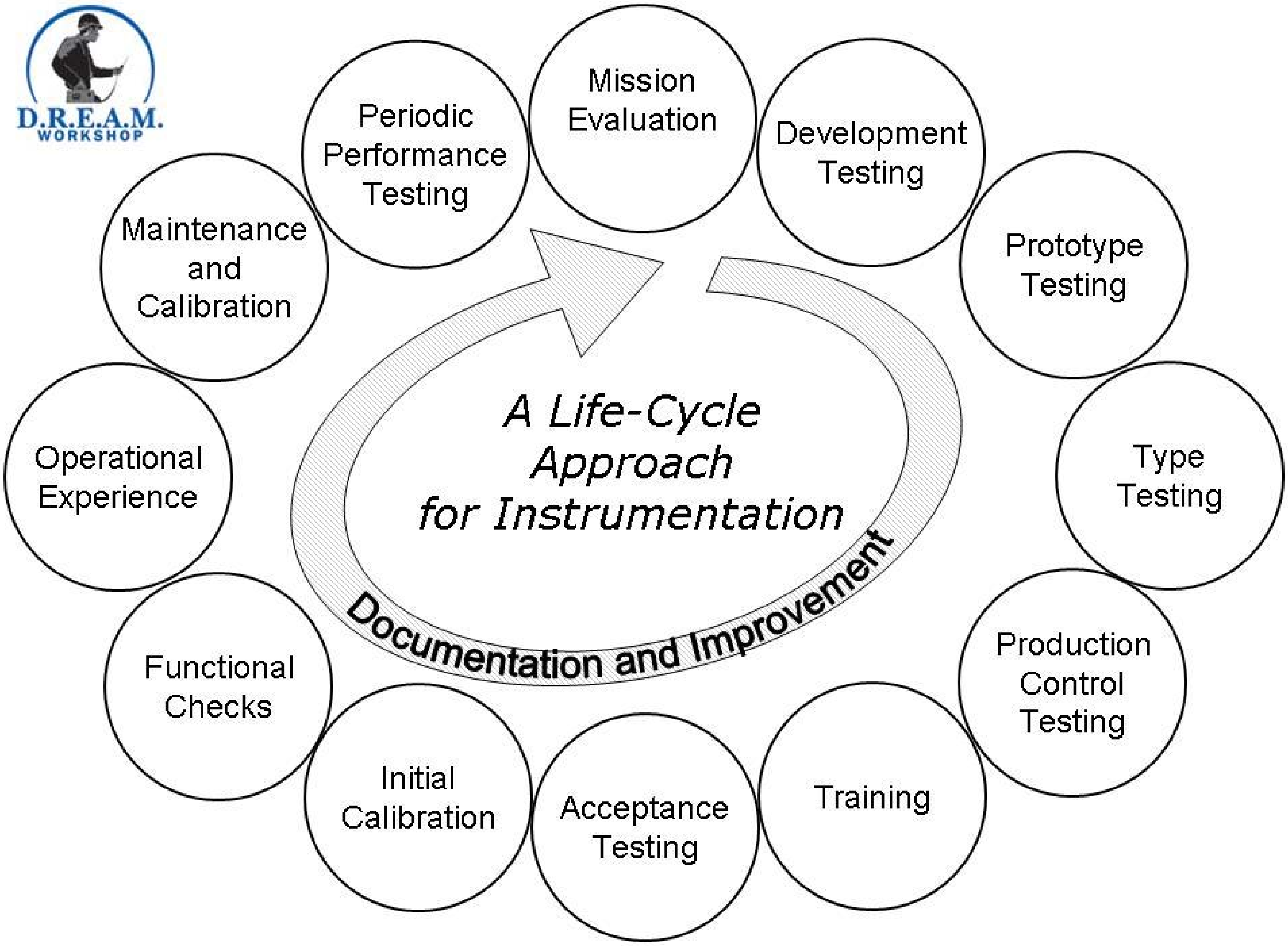
Rapporteur Report

Hazard Session: Radiation

Monitor: Mark Hoover (and Jeri Anderson)
National Institute for Occupational Safety & Health

Co-Monitor: Cynthia Jones
U.S. Nuclear Regulatory Commission

Rapporteur: Pamela Drake
National Institute for Occupational Safety & Health


Mission Evaluation
Development Testing
Prototype Testing
Type Testing
Production Control Testing
Training
Acceptance Testing
Initial Calibration
Functional Checks
Operational Experience
Maintenance and Calibration
Periodic Performance Testing
A Life-Cycle Approach for Instrumentation
Documentation and Improvement

Status of current DRM for radiation detection/exposure assessment

- Extensive knowledge of radiation physics and measurement (including anomalies)
- Can measure at levels lower than hazardous
- Current success with miniaturization
- Photons = mature (rate, total, spectral)
- Alpha, beta, neutrons = need work

Status of current DRM for radiation detection/exposure assessment

- Extensive knowledge of radiation physics and measurement (including anomalies)
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- Alpha, beta, neutrons = need work

Status of current DRM for radiation detection/exposure assessment

- Serves as a model for other threat agents
- Graduated Radiation/Nuclear Detector Evaluation and Reporting Program
- Responder Knowledge Base (Web-based reference)

Research Needs

- Develop bio methods that are direct reading, efficient, and available
  - Biodosimetry
  - Bioassay
- Reduce size and increase speed of neutron detectors for all energies
- 3rd party independent testing of instruments
- *Develop methods and standards for immediate first-responder detection of airborne particulates (CBRN)*

Data management challenges

- IEEE 1451 series -- harmonization of data acquisition and transmission
- ANSI 42.42 -- data format (for all sensors)
- ANSI 42.36 -- RADnet standard for data transmission
- Voice, video, data, positioning (GIS, GPS)

Possible NIOSH Roles

1. Evaluate and report on operational experiences with various instruments in various industries
   - Cover routine and emergency operations
   - Include national and international input
   - Transfer emerging technologies to the US
2. Expand role on the Interagency Board (IAB) for Equipment Standardization and Interoperability (CBRN)

Possible NIOSH Roles

3. Expand role in development of national and international standards
4. Identify gaps in safety practices nationwide
   - Develop training materials and guidance to bridge the gaps
   - Identify opportunities for DRM solutions
5. Collaborate with stakeholders to develop and implement new and improved methods
   - National laboratories, federal agencies, users, manufacturers

Rapporteur Report

Session 6: Surface Sampling/Biomonitoring

Monitor: John Snawder
National Institute for Occupational Safety & Health

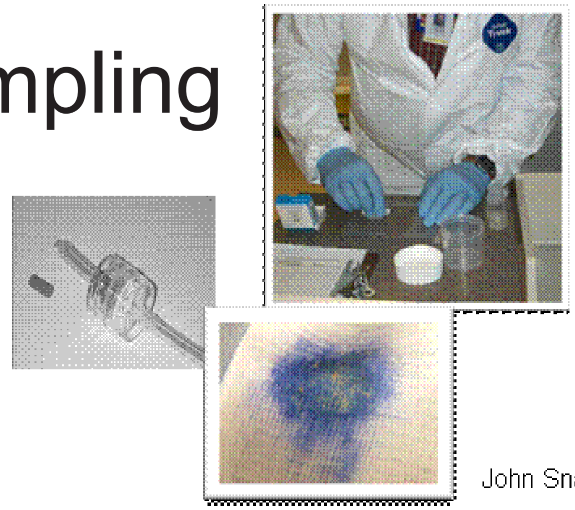
Co-Monitor: Matthew Magnuson
Environmental Protection Agency

Rapporteur: Deborah Sammons
National Institute for Occupational Safety & Health

Speakers

- Michael Philips
  - Menssanna Research, Inc.
- Charles Timchalk
  - Pacific Northwest National Laboratory
- Jayne Morrow
  - National Institute of Standards and Technology
- Wassana Yantasee
  - Pacific Northwest National Laboratory
- Kevin Ashley
  - National Institute for Occupational Safety and Health

Surface Sampling

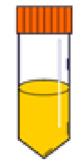


John Snawder

- Surface Sampling
  - Types
    - Wipes
    - Swabs
    - Tape
    - Vacuum
    - Dermal
    - Bulk
  - Considerations
    - Characteristics of sample
    - Type of surface
    - Transfer of sample
    - Extraction/recovery of sample
    - Matrix of sample

Kevin Ashley

Biomonitoring



- Biomonitoring
  - Blood
  - Urine
  - Saliva
  - Sperm
  - Tissue
  - Bronchial lavage
  - Exhaled breath
- Assess worker exposure
- Evaluate effectiveness of engineering controls or other exposure reduction/ preventive measures

Chicken or the Egg?

- Surface Sampling
  - Source of contaminant
- Biomonitoring
  - Measured analyte or marker in biological fluid

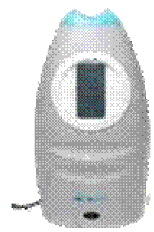
Where have we been?
Where are we going?

- Laboratory Based Analysis
  - Complicated
  - Requires extensive training
  - Expensive
  - Time consuming requiring sending samples out

- Field Portable
  - Convenient for worker (Spirometry)
  - Miniaturized (ELISA- portable spectrophotometers), but not necessarily real time

- Direct Reading Instruments
  - Real time
  - No or minimal sample preparation
  - Cost effective
  - User friendly but require training

NIOSH Efforts



- Application of Commercial/ Clinical Point of Care Instruments in the Field
-
  - TobacAlert- cotinine
  - Testmate AchE- Acetylcholinesterase
  - Avox
  - LeadCare- blood lead
  - Niox- Nitric oxide

NIOSH Efforts Development and Commercialization of Kits

- Lead Wipes for surface sampling, NMAM 9105
- Licensed to SKC inc as “Full Disclosure”

Kevin Ashley

NIOSH Efforts

- Methamphetamine surface wipe methods, NMAM Draft 9106,9109,9111 by MassSpec with isotopic dilution.

- 2 Direct Reading Methods, Colorimetric and Immunochemical. Licensed to SKC as “MethAlert” “MethChek”

NIOSH Efforts Development of Lateral Flow Cassettes

- Anti Protective antigen of *B anthracis* in serum, plasma and whole blood

- Antineoplastic drugs on surfaces
  - Paclitaxol
  - 5-Fluorouracil (5FU)

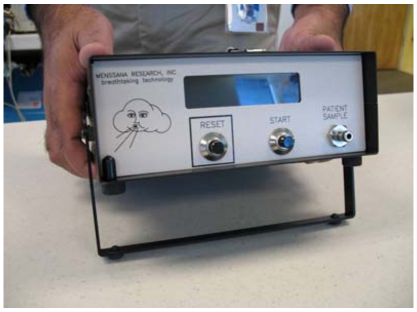
Uses of Direct Reading Methods

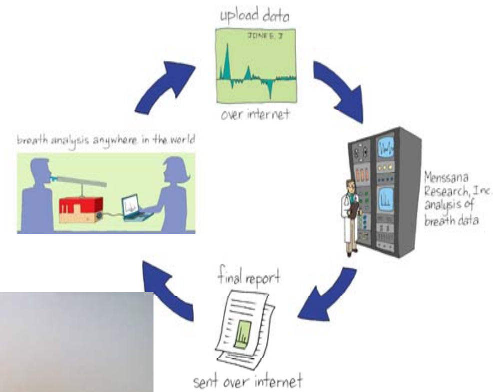
- Lead hand wipes
- Identification of Exposure/Exposure Assessment
- Evaluation of Cleanup or Controls
- Worker Empowerment

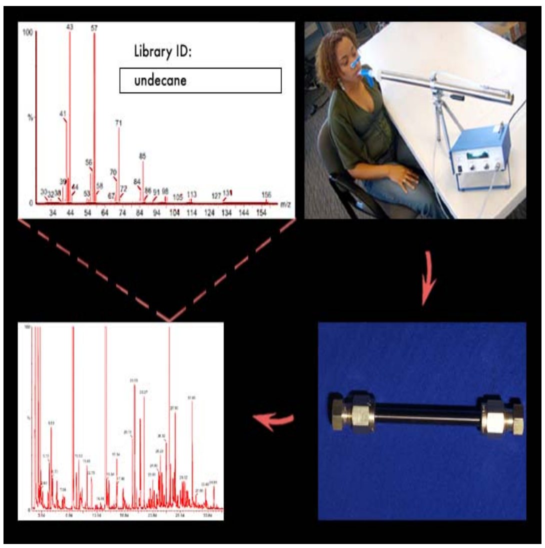
Advantages/Challenges

- Advantages
  - Low cost
  - Rapid
  - High throughput
  - Sensitive
- Challenges
  - Sampling strategies, reference materials, reference values
  - What do the results mean
  - Field versus lab validation
  - Breath analysis- Regulation nightmare to market products

Future Applications- VOCs in Exhaled Breath





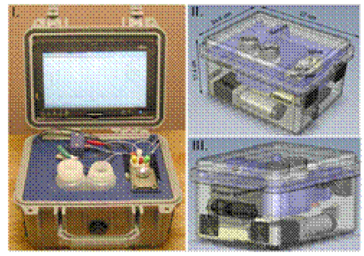


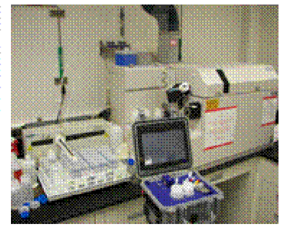
Michael Philips

Future Applications- Electrochemical Sensors for Chemical Mixtures

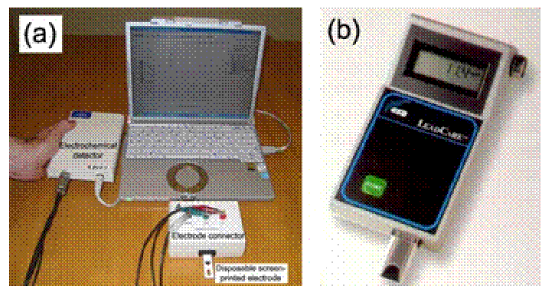
- Sequential/injection immunoassay for quantitation of trichloropyridinol (metabolite of chlorpyrifos)-ppt
- Carbon nanotube-sensor for quantitation of cholinesterase activity
- Nano-particle immunosensor for phosphorylated AChE

Future Applications-
New Generation Sensors for Pb, Cd, and Hg





- Functional silica (SAMMS) Sensors
  - Self assembled monolayers on mesoporous supports



- Magnetic nanoparticle sensors

Yantasee, Wassana

Top Five Research Needs

1. Standardization of instruments and defined performance specifications.
2. Address accreditation issue. DRM/DRI need to be accepted after validation and accreditation, they to be defensible in court. Need a workshop on accreditation and training.
3. Training
4. Know what qualifies as an acceptable DRM or screening method. Need action levels.
5. New biomarkers and sensors. Perhaps partner with something like NIEHS gene environment interaction program. Other medical diagnostic tests used as DRMs. Need means to look at exhaled breath.

Research Agenda

Stakeholder input to identify top problems

http://www.cdc.gov/niosh/nora

Updates on the progress of NORA

http://www.cdc.gov/niosh/enews/

Refined DRM Research Priorities

All of the breakout groups determined that research should seek to develop new or refined technologies that meet sector-specific DRM needs, and several addressed the question of how to encourage product development for niche markets. Other recurring themes emerged from the breakout group reports:

- Worker empowerment involves educating and training users to better understand how specific DRMs work, what the DRMs can and cannot do, and how to interpret the data from their DRMs.
- In nearly every setting, standards are needed to ensure the accuracy of DRMs and to validate their performance.
- Efforts are needed to speed the transition from research to real-world application of DRMs.

The criteria for exposure must be re-evaluated or defined in several sectors.

Session 1: Gases and Vapors

Research Priorities

1. Pursue gas chromatography miniaturization, which could be coupled with other detectors, sensor arrays, or mass spectrometry, for example, to identify one compound within a mixture.
2. Explore workers' ability to measure their own exposures. To accrue more data, evaluate options that are simple, cheap, and provide high throughput. Some accuracy may be sacrificed to provide more raw data.
3. Refine existing technologies and improve their sensitivity and selectivity, e.g., for detecting toxic gases, hydrogen sulfide, and carbon monoxide.
4. Make devices multi-functional, e.g., capable of recording chemicals present, temperature, and heart rate and incorporating global positioning systems.
5. Develop self-calibrated systems, eliminating the need for gas transport.
6. Focus on "niche" DRMs, e.g., for formaldehyde, hafnium, chloramines (for the poultry industry), nicotine, R-N=C=O. Explore how NIOSH can contribute to development of DRMs with narrow market applications and that are unlikely to be commercially successful.
7. Establish NIOSH-OSHA collaboration to transition new DRMs to compliance-acceptable status.
8. Develop DRMs for unknown chemical components in mixtures.
9. Seek methods for worker empowerment, e.g., DRMs that give feedback directly to workers, thus giving them options to modify their behavior or environment.

Session 2: Aerosols

Research Priorities

1. Conduct basic research on how instruments respond to different aerosol characteristics.
2. Invent/continue development of aerosol monitors, especially agent-specific monitors (not just dust).
3. Develop consensus standards on accuracy and validation with input from manufacturers, OSHA, and other stakeholders. NIOSH should not be responsible for validating instruments.
4. Develop standards for performance and use of monitors.
5. Develop sector-specific education and guidance on use of monitors in specific environments.

Session 3: Ergonomics

Research Priorities

1. Assess the specific needs of specific customers for DRMs (e.g., researchers, practitioners, workers). The relativity immaturity of the field demands that more basic research be conducted.
2. Develop technologies to measure exposure dose or improve existing technology (e.g., through miniaturization or better usability).
3. Investigate pathophysiological processes associated with exposure (e.g., biomonitoring for tissue response as an indicator of musculoskeletal outcomes).
4. Establish valid exposure assessment criteria. Currently, no exposure limits exist.
5. Translate research into practical instruments for DRMs.

Session 4: Noise

Research Priorities

1. Reexamine the basis for current damage risk criteria. Mr. Kardous called for seeking universal consensus on a new set of criteria.
2. Determine the relationship between DRMs, metrics, and behavior modification to understand whether workers change their behavior in response to instant feedback from a monitor.
3. Develop new sensor technology (e.g., microphones, acoustic mannequins) that can be used in more settings, such as law enforcement.
4. Develop a repository of exposure and risk data to help assess damage risk criteria and develop metrics, for example. Divisions throughout NIOSH have decades' worth of research data that could be linked together to create a rich database for analysis.

Session 5: Radiation

Research Priorities

1. Develop new technology for biological DRMs that are direct-reading, efficient, and available, using biodosimetry and bioassays, for example, which are already in use overseas.
2. Reduce size and increase speed of neutron radiation detection for all energies.
3. Establish mechanisms for independent third-party testing of instruments.
4. Develop methods and standards for detecting airborne particles (for chemical, biological, radiological, and nuclear threats) for immediate first responders.

Potential roles for NIOSH:

- Evaluate and report on real-life operator experience with instruments in various industries—both routine and emergency operations, international and domestic populations—and the possible transfer of emerging technology to the United States.
- Expand participation in the Inter-Agency Board to develop equipment standards and enhance interoperability for all chemical, biological, radiological, and nuclear threat detection approaches.
- Expand role in developing national and international standards.
- Identify gaps in safety practices nationwide. Develop training materials and guides to bridge gaps. Identify opportunities for solutions using DRMs.
- Collaborate with stakeholders on development and implementation of new DRMs.

Session 6: Surface Sampling & Biomonitoring

Research Priorities

1. Develop standards to ensure that products live up to manufacturers' claims and to identify what a given product can or cannot do in various circumstances. One organization should oversee standards development.
2. Address accreditation to further ensure manufacturers adhere to standards and ensure that accreditation mechanisms are defensible in court.
3. Establish training for users on how DRMs work, what they can and cannot do, and how to interpret results.
4. Determine the purpose of DRMs (e.g., screening, mitigation) and what constitutes an acceptable DRM for that purpose. Action levels (i.e., exposure levels that require action be taken) are needed but should be developed after standards are established.
5. Identify new biomarkers and sensors, partnering with other organizations to leverage time and funds and seeking new uses for existing technology.

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, OH 45226-1998

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